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THE STRATIGRAPHY OF THE OREGONIA–FT. ANCIENT REGION, SOUTHWESTERN OHIO.

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The Oregonia-Ft. Ancient region is located in the vicinity of the villages of Oregonia and Ft. Ancient, along the Little Miami River in Warren County, southwestern Ohio. It has an area of approximately 50 square miles, and is enclosed principally within the Morrow quadrangle of the U. S. Geological Survey. The region has several times been referred to by geologists*, and the Mound Builders' work at Ft. Ancient is widely known, but there is in the literature no detailed treatment of the stratigraphy of the district.

The author acknowledges his indebtedness to Dr. J. Ernest Carman, of Ohio State University, and to Dr. W. H. Shideler, of Miami University, who have aided very materially by their helpful suggestions and criticisms.

PHYSIOGRAPHY OF THE REGION.

The Oregonia-Ft. Ancient region is located in the Glaciated Plains section of southwestern Ohio. The upland of the region is a gently rolling plain, and the region is thoroughly dissected by a well established drainage system. The trunk stream of the district is the Little Miami River, which crosses our area from north to south in a relatively narrow and steep-sided valley. The distance from rim to rim of the valley is less than a mile, even where widest, and the depth is about 250 feet. Bordering

*Geol. Surv. Ohio, III, Part 1, pp. 381–391.
Proceedings of the U. S. National Museum, Vol. 70, Art. 22, pp. 1–18.
Bull. Scientific Lab., Denison Univ., Vol. XIX, June, 1919, pp. 65–81.

the major valley, there is a belt about one mile wide that is thoroughly dissected by gullies and ravines that are cutting back into the upland. Larger tributaries carry this dissection farther from the main valley, but with decreasing ruggedness, until it merges into the upland topography.

The upland of the region is mantled with glacial drift to an average thickness of about 35 feet. The streams and larger ravines of the district have cut through this mantle of drift, and are cutting into the bed rock beneath. It is along these stream courses that most of the exposures of bed rock in the region exist, but in general the ravines do not give continuous exposures for any considerable distance.

PLATE I.

VARIOUS CLASSIFICATIONS OF THE CINCINNATIAN SERIES.

ORTON (1873)	WINCHELL-ULRICH (1897)	NICKLES-FOERSTE (1905)		ULRICH-BASSLER (1906)		FOERSTE* (1910–11)		CUMINGS (1922)	
Lebanon	Richmond	Richmond	Saluda Whitewater Liberty Waynesville	Richmond Group	Saluda Whitewater Liberty Waynesville Arnheim	Richmond	Elkhorn Whitewater Saluda Liberty Waynesville Armheim	Richmond	Elkhorn Whitewater Saluda Liberty Waynesville Arnheim
Hill Quarry	Lorraine	Maysville	Arnheim Mt. Auburn Corryville Bellevue Fairmount Mt. Hope	Covington Group	McMillan Fairview	Maysville	Mt. Auburn Corryville Bellevue Fairmount Mt. Hope	Maysville	Mt. Auburn Corryville Bellevue Fairmount Mt. Hope
Eden	Utica	Eden	Upper Middle Lower		McMicken Southgate Economy Fulton	Eden	McMicken Southgate Economy Fulton	Eden	McMicken Southgate Economy

* Foerste, in the Geologic Map of Ohio, 1920, places the Maysville-Richmond division plane at the base of the Oregonia member of the Arnheim division.

STRATIGRAPHY.

The Oregonia-Ft. Ancient region is situated approximately on the crest of the Cincinnati Arch, and the strata are essentially horizontal and undeformed.

The strata of the region belong to the Ordovician system, and principally to the Richmond sub-series. The subdivisions and classification of the Cincinnatian series have suffered many changes and corrections during the last 50 years, and there is not yet complete agreement on all points. This is especially true of the Maysville-Richmond sub-series boundary, which is well exemplified in our region. It is with this question that this paper is primarily concerned.

The subdivisions of the Cincinnatian series as used by the several authors are shown and correlated on Plate I. The column of subdivisions used in this report, which is a composite from several published columns is as follows, the subdivisions exposed in the Oregonia-Ft. Ancient region being in *italics*. The thicknesses given are for the Oregonia-Ft. Ancient region.

(System)	(Series)	(Sub-series)	(Formation)	(Member)	Thickness
Ordovician..	Cincinnatian	*Richmond*...	Elkhorn		
			Whitewater		24′ +
			Liberty		28′ 1″
			Waynesville....	*Blanchester*	35′ 1″
				Clarksville	24′ 8″
				Ft. Ancient	36′ 8″
			Arnheim.....	*Oregonia*	23′ 9″
				Sunset	35′
		Maysville...	*McMillan*.....	*Mt. Auburn*	16′ 6″
				Corryville	15′ 2″+
				Bellevue	
			Fairview.....	Fairmount	
				Mt. Hope	
		Eden.....	Latonia.....	McMicken	
				Southgate	
				Economy	
			Utica		
	Mohawkian				
	Canadian				

The Cincinnatian series is made up largely of shale, and subordinately of limestone. The general succession throughout the series is an alternation of layers of shale and limestone, the shale layers commonly being thicker. A composite geologic section of the Oregonia-Ft. Ancient region is as follows:

Thickness

THE RICHMOND SUB-SERIES.

THE WHITEWATER FORMATION: 24′ exposed; best exposed in Flat Fork.

42. Irregularly bedded, argillaceous limestone and relatively even-bedded, blue-gray shale ..... 12′ 0″

The whole assumes a distinctive cream color upon weathering. Principal fossils are: *Byssonychia obesa, Strophomena sulcata, S. planumbona, Rafinesquina alternata, Rhynchotrema capax, Platystrophia acutilirata, Hebertella occidentalis, Dinorthis subquadrata, Monticulipora epidermata, Homotrypa wortheni, Bythopora delicatula, Batostoma variable, Streptelasma rusticum, S. divaricans* and *Protarea richmondensis.*

41. Alternating layers of irregularly-bedded, argillaceous limestone and nodular shale. Fauna essentially the same as that of Zone 42, except that *Streptelasma rusticum* is especially large and abundant at this horizon ..... 6′ 8″

40. Alternating layers of limestone and shale between base of 3½-inch limestone layer at top of zone, and base of "Turkey Track" limestone layer below ..... 5′ 4″

This Turkey Track layer is a hard, fine-grained, essentially barren limestone layer approximately 7 inches thick, the top of which bears impressions resembling turkey tracks. The base of this Turkey Track layer has been designated by Dr. George M. Austin as the plane of division between the Whitewater and Liberty formations in southwestern Ohio.

Above the Turkey Track layer is a series of hard, fine-grained relatively unfossiliferous limestone layers, most of which bear surface impressions of rill marks or seaweeds. Between these dense, unfossiliferous limestone layers, are layers of blue-gray shale that are relatively fossiliferous. This zone marks a sudden ingress of fossils unusual to the lower Richmond formations. The specimens are not abundant, but a close search will disclose numerous species, several of which are as yet undescribed. Chief among these unusual forms are curved and coiled Cephalopods of the *Gomphoceras, Cyrtoceras* and *Trochoceras* types. The Pelecypods *Whitella, Ischyrodonta* and *Opisthoptera* and others exist at this horizon.

THE LIBERTY FORMATION ..... 28′ 1″

39. Alternating layers of fine-grained, blue shale and even-bedded limestone ..... 8′ 5″

Principal fossils are: *Strophomena planumbona, Plectambonites richmondensis, Platystrophia annieana, Rhynchotrema capax, Rafinesquina alternata, Hebertella occidentalis, Dinorthis subquadrata, Rhombotrypa quadrata, Streptelasma rusticum, S. divaricans, Protarea richmondensis* and others. This zone, as well as the other ones of the Liberty formation, are best exposed in Flat Fork and Olive Branch.

38. Limestone zone which in most stream exposures caps a falls above the Isotelus shale zone ..... 2′ 5″

37. Isotelus shale ..... 5′ 11″

Even-bedded, plastic, blue shale with a few thin limestone partings. At this horizon, in the valley of Flat Fork, a very fine large specimen of the Trilobite *Isotelus brachycephalus* was found. This specimen is quite complete and measures 11¼ inches in length by 8 inches across at the posterior edge of the cephalon. Fragments of Isotelus are common at this horizon, but complete specimens are rare. The principal other fossils found in this zone are: *Calymene meeki, Rafinesquina alternata, Pterinea demissa, Ctenodonta, Lophospira bowdeni* and *Columnaria alveolata.*

36. Alternating layers of blue shale and thin limestone partings, which form a series of small falls in most stream exposures..... 11′ 4″

Fauna essentially the same as that of Zone 37, except that *Plectambonites richmondensis* is especially abundant near the top of this zone.

THE WAYNESVILLE FORMATION:

The Blanchester Member..... 35′ 1″

Well represented in Blacksmith Hollow, Flat Fork and Olive Branch.

35. Upper Hebertella insculpta zone ..... 5′ 7″

Top of zone marked by a 3 to 4 inch, more or less wave-marked limestone layer containing *Hebertella insculpta, Strophomena planumbona, Rhynchotrema capax* and other fossils. Below this uppermost layer of limestone is a 30 inch division composed principally of shale, relatively barren of fossils. The basal part of this zone is composed of alternating laters of shale and thin partings of limestone, and contains principally the Brachiopods *Hebertella insculpta* and *Strophomena planumbona.*

34. Blue shale with thin limestone partings containing fragments of *Isotelus, Calymene meeki, Pterinea demissa, Byssonychia radiata, Tetradium, Columnaria alveolata* and *Calapoecia cribriformis*..... 4′ 3″

33. Alternating blue shale and even-bedded limestone layers..... 10′ 1″

Eleven inches below top of zone is a one-inch, even-bedded limestone layer to which the Brachiopod *Plectorthis scovillei* is confined. Other fossils of the zone are: *Zygospira modesta, Rafinesquina alternata, Plectambonites richmondensis, Platystrophia cumingsi* (?), *Leptaena richmondensis, Hebertella occidentalis, Homotrypa dawsoni, Protarea richmondensis, Streptelasma rusticum, S. divaricans* and others.

32. Blue shale and thin limestone layers containing *Strophomena nutans* and *S. neglecta*..... 2′ 10″

31. Even-bedded, blue shale with a few thin limestone partings containing principally fragments of *Isotelus*, several species of *Pelecypods, Leptaena richmondensis, Dalmanella meeki* and *Bythopora meeki*..... 6′ 9″

30. Thin, irregularly-bedded limestone and nodular shale layers. Fossils jumbled and broken..... 5′ 8″

29. Lower Hebertella insculpta zone, the base of which marks the Blanchester-Ft. Ancient division plane..... 0′ 11″

The Clarksville member..... 24′ 8″

Best exposed in Stony Run, Blacksmith Hollow and Longstreth Branch.

28. Alternating thin limestone and blue shale layers..... 6′ 1″

Principal fossils are: *Strophomena planumbona, Leptaena richmondensis, Hebertella occidentalis, Dalmanella meeki* and *Streptelasma rusticum.*

27. Zone of the usual succession of shale and limestone, containing principally: *Zygospira modesta, Plectambonites richmondensis, Platystrophia clarksvillensis, Leptaena richmondensis, Dalmanella meeki* and *Streptelasma rusticum*..... 5′ 2″

26. Alternating shale and thin limestone layers, crowded with: *Strophomena planumbona, Platystrophia clarksvillensis, Hebertella occidentalis*, all more or less jumbled together..... 5′ 4″

25. Coarse-grained, irregularly-bedded limestone layers with thin partings of blue shale. *Dalmanella meeki* abundant, and jumbled together..... 2′ 8″

24. Fine-grained, even-bedded, blue shale commonly referred to as the Orthoceras duseri shale or the Trilobite Beds because of the relative abundance of *Orthoceras duseri* and *Calymene meeki* at this horizon. Other fossils common to the zone are: fragments of *Isotelus*, several species of *Pelecypods*, *Cyphotrypa clarksvillensis*, *Tetradium huronense* (?), and *Stromatocerium huronense* (?)..... 5′ 5″

This zone was formerly classified with the Ft. Ancient member, but Dr. Shideler places it in the Clarksville member because of the existence therein of Tetradium and Stromatocerium—Richmond forms not present in the Ft. Ancient member.

The Ft. Ancient member.....36′ 8″

Most completely represented in Blacksmith Hollow, Longstreth Branch and Stony Run.

23. Alternating shale and thin limestone layers containing principally *Rafinesquina alternata* and *Dalmanella meeki*..... 3′ 0″

22. Even-bedded, blue shale with thin limestone partings. Base of zone marked by a three-inch, wave-marked limestone layer. Most abundant fossils are: *Pterinea demissa*, *Modiolopsis concentrica*, *Byssonychia radiata*, *Anomalodonta gigantea*, *A. alata*, *Zygospira modesta*, *Rafinesquina laternata* and *Dalmanella meeki*.. 8′ 0″

21. Blue shale with a few thin limestone partings; fossils essentially the same as in zone above..... 8′ 8″

20. Zone of nodular shale and thin, argillaceous limestone layers, with a three-inch dense limestone layer at top of zone. Fossils jumbled and broken..... 3′ 6″

Rafinesquina alternata and *Dalmanella meeki* predominate in number, almost to the exclusion of other forms.

19. Alternating layers of irregularly-bedded, argillaceous limestone and nodular, blue shale containing principally jumbled and broken specimens of *Calymene meeki*, *Cornulites sterlingensis* (?), *Zygospira modesta*, *Rafinesquina alternata* and *Dalmanella meeki*..10′ 6″

18. Irregularly-bedded limestone layers with thin shale partings. Shale relatively barren of fossils, and limestone layers composed chiefly of fossil fragments and jumbled specimens of *Dalmanella meeki*..... 3′ 0″

The Arnheim Formation:

Best exposed in Blacksmith Hollow and Longstreth Branch.

The Oregonia member.....23′ 9″

17. Conspicuous zone of nodular, irregularly-bedded, argillaceous limestone layers that weather into lumps. Fossil fragments are abundant throughout the zone, indicating shallow water conditions of deposition, but the only unbroken specimens found were a few *Pterinea demissa*, *Anomalodonta gigantea*, *A. alata*, *Cornulites sterlingensis* (?) and a single *Strophomena concordensis*..... 5′ 6″

16. Alternating layers of coarse-grained, irregularly-bedded limestone and nodular shale. Fossils include those of Zone 17, plus *Cyclonema bilix*, *Rafinesquina alternata*, *Dalmanella meeki*, *Peronopora decipiens*, *Mesotrypa orbiculata*, *Homotrypa bassleri*, *Ceramoporella ohioensis*, *Batostoma varians* and many microscopic size specimens of Pelecypods, Gastropods, Brachiopods and Bryozoa, several of which are undescribed.....12′ 8″

15. Zone of shale and limestone layers; top marked by even-bedded limestone layer with nodules of Pyrite..... 1′ 2″

14. Dinorthis carleyi zone..... 4′ 5″
Thin layers of shale and limestone containing *Dinorthis carleyi, Trematis millipunctata, Leptaena richmondensis, Stigmatella crenulata, Rhopalonaria venosa* and *Batostoma varians*. The first appearance of the Brachiopod Dinorthis carleyi marks the base of the Oregonia member.—(A. F. Foerste, Ohio Naturalist, XII, Jan. 1912, p. 436.)

The Sunset member.....35′

13. Lumpy shale and thin, irregularly-bedded limestone layers. The Brachiopod *Leptaena richmondensis* first appears in the Richmond division at this horizon..... 1′ 6″

12. Alternating blue shale and thin limestone layers, relatively barren of fossils..... 2′ 3″

11. Irregularly-bedded limestone and nodular shale layers..... 1′ 9″

10. Zone of nodular blue shale and thin limestone layers. Characteristic fossils are: *Rafinesquina alternata, Delmanella meeki, Stigmatella crenulata, Rhopalonaria venosa, Peronopora decipiens, Mesotrypa orbiculata, Homotrypa libana, H. flabellaris, Hallopora subnodosa* and *Ceramoporella ohioensis*..... 5′ 6″

9. Covered interval.....15′ 8″

8. Even-bedded, blue-gray shale with thin limestone layers containing principally: *Calymene meeki, Dalmanella meeki, Stigmatella crenulata, Peronopora decipiens, Homotrypa libana, H. flabellaris, Hallopora subnodosa* and *Ceramoporella ohioensis*..... 7′ 4″
Practically all of these are typical Richmond forms, not found in the underlying Mt. Auburn division. The characteristic Maysville fossils, with but few exceptions, either do not continue into the Richmond division, or are recognizably modified. At least half of the species that do survive are hardy forms that have lived on since Bellevue time.

7. Alternating layers of coarse-grained, very irregularly-bedded limestone layers with thin shale partings..... 1′ 0″
The fossils in this zone are jumbled and broken, indicating shallow-water conditions of deposition. Traced southward into Brown and Adams counties, Ohio, this horizon exhibits strongly developed cross-bedding. And in Kentucky, these strata are ripple-marked, sun-cracked and marked with raindrop impressions, indicating not only shallow water conditions, but a definite period of emergence between the deposition of the Maysville and Richmond subseries in that province.*
The base of this zone is regarded as the plane of division between the Richmond subseries above, and the Maysville subseries, below. Dr. Ulrich would make this horizon the systemic boundary between the Silurian and Ordovician systems.

THE MAYSVILLE SUB-SERIES.

THE MT. AUBURN FORMATION.....16′ 6″

6. Blue-gray, even-bedded shale with thin partings of limestone, in which the fossils lie undisturbed in a practically horizontal position. The principal fossils of the zone are: *Zygospira modesta, Rafinesquina alternata,* the distinctive Mt. Auburn Bryozoan *Homotrypa pulchra, Heterotrypa frondosa* and *Ceramoporella ohioensis*..... 2′ 5″

5. Irregularly-bedded limestone and nodular shale layers in which exist *Rafinesquina alternata, Homotrypa pulchra, Heterotrypa frondosa, Hallopora rugosa* and *Ceramoporella ohioensis*, all more or less jumbled together..... 4′ 7″

*Personal communication from Dr. W. H. Shideler, Miami University.

4. Alternating layers of irregularly-bedded argillaceous limestone with nodular shale layers..... 4′ 10″
   Platystrophia ponderosa auburnensis, the characteristic Mt. Auburn Brachiopod, is abundant in this zone, but was not found in the zones above.
3. Lumpy shale and irregularly-bedded limestone layers..... 4′ 8″
   Fossils jumbled and broken. Principal species are: *Byssonychia radiata, Cyclonema bilix, Rafinesquina alternata* abundant, *Platystrophia ponderosa* present but relatively scarce.

THE CORRYVILLE FORMATION.....15′ 2″ exposed

2. Irregularly-bedded, argillaceous limestone layers and lumpy shale..... 8′ 8″
   Fossils jumbled, with *Rafinesquina fracta* most abundant; other forms are: *Pterinea demissa, Zygospira modesta* and the characteristic Corryville Bryozoan *Chiloporella flabellaris*. No Platystrophia ponderosa exist in this zone, the first appearance of this species in the zone immediately above marking the base of the Mt. Auburn division.
1. Alternating layers of shale and limestone containing *Chiloporella flabellaris* and *Rafinesquina fracta*, the latter occurring as jumbled masses at several horizons within the zone..... 6′ 6″

SUMMARY AND CONCLUSIONS.

The bed rock of the Oregonia-Ft. Ancient region includes Cincinnatian strata ranging in age from the Corryville member of the Maysville sub-series, to the Whitewater formation of the Richmond division, inclusive.

Regarding the controversial Maysville-Richmond sub-series boundary; the preponderance of evidence shows conclusively that it should be placed at the top of the Mt. Auburn division. In our region, indications at this horizon point to a shoaling of the Maysville sea. Traced southward through Ohio and into Kentucky, we find evidence of very shallow water conditions and even temporary withdrawal of the sea at this horizon. There is also a marked faunal break at this horizon. The characteristic Maysville forms, with but few exceptions, fail to pass this stratigraphic break between the Mt. Auburn and Sunset divisions; and those that do survive the transition are hardy forms that have lived on since Bellevue time. And even these surviving forms are recognizably modified. Moreover, the first fossiliferous strata in the Arnheim division carry a characteristic Richmond fauna; forms that for the most part do not exist in the underlying Maysville sub-series, but are typically developed in the succeeding Richmond sub-series.

DRAINAGE CHANGES IN THE VICINITY OF WOOSTER, OHIO.

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In a pamphlet* published by the Ohio Academy of Science, Dr. J. H. Todd has presented a paper, setting forth his theories concerning the preglacial drainage of Wayne and adjacent counties. Results of investigations within recent years by G. W. Conrey, G. Coffey and the author, throw serious doubt on the correctness of Todd's conclusions. In the light of evidence now available it seems desirable to offer an explanation in accord with facts.

For a detailed discussion of the old theory of the preglacial drainage, the writer refers the reader to the original paper by Dr. Todd, mentioned in the previous paragraph. For the benefit of those who are without information concerning the problem it is perhaps expedient to give, as briefly as possible, a general lay-out of the preglacial drainage conditions as put forth by Dr. Todd. (Figure 1).

Todd agrees with others who have studied Ohio, that the preglacial drainage in this region was to the north in the direction of Lake Erie, instead of to the south as at present. He traced the course of a large stream by way of the broad, drift-filled valley which extends from Mansfield to Loudonville and Shreve. From Shreve its course was northeastward to Wooster, in the valley now followed by the Pennsylvania Railroad; this railroad follows the old valley from Mansfield to Wooster. From Wooster the stream, it is believed, flowed across a broad divide to a point near Orrville, from which it followed the old valley now occupied by Little Chippewa Creek, where it took a northwesterly course leaving Wayne County north of Sterling. From that point its channel was northward by way of Chippewa Lake, passing to the east of Medina and farther north into the valley now occupied by the West Branch of the Rocky River. Tributary streams joined

*Todd, J. H. "Some Observations on the Preglacial Drainage of Wayne and Adjacent Counties," Ohio State Academy of Science, Special Papers, No. 3, pp. 46-67, December, 1900.

this main or trunk stream at various places. Todd places considerable importance on the bed rock as a controlling agent, determining the direction of flow; emphasizing the significance

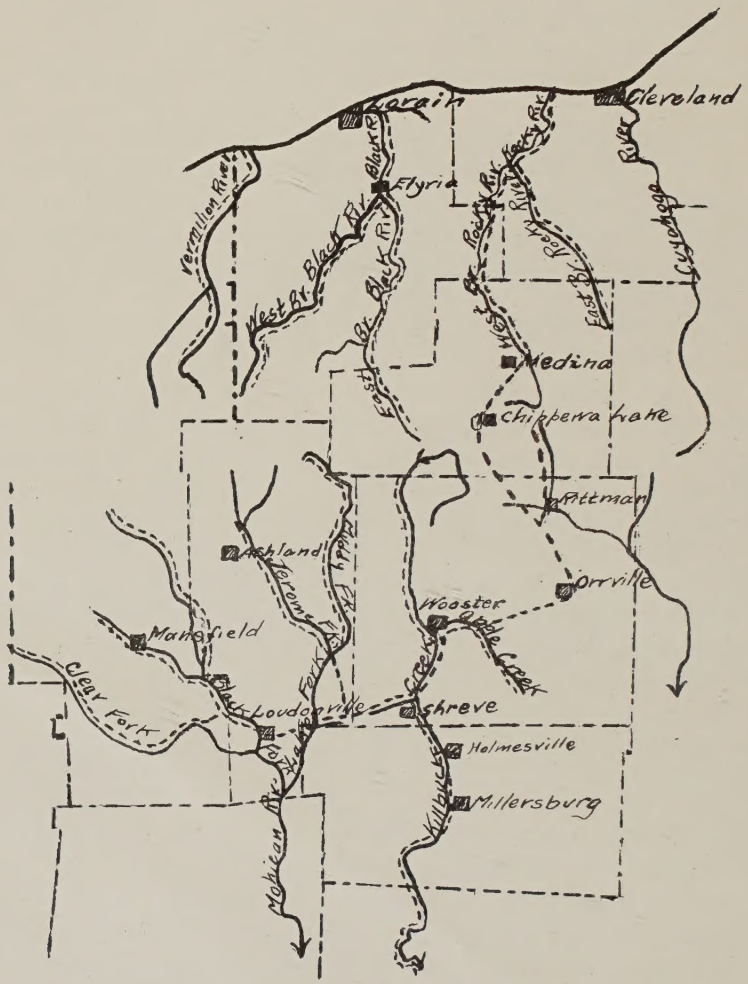

FIG. 1. Sketch map showing present and pre-glacial drainage lines in Wayne and adjacent counties, according to J. H. Todd. Dotted lines indicate pre-glacial drainage.

of the position of the stream between the Waverly-capped hills to the north and west and the Coal Measures to the east and south*.

*Ibid., I, pp 46–49.

The course of the stream can be traced to Wooster (Figure 2) where insuperable difficulties are encountered; the broad valley ends abruptly. Todd recognizes this difficulty, for he remarks†, "This brings me to the city of Wooster, and from here to Orrville I have a rough road to travel, but the preglacial water came here, and there was but one way for it to go out, and I must find that way under the high gravel hills between here and Orrville. On the south of Wooster is Madison Hill, on which is located the Ohio Experiment Station with its quarry

FIG. 2. Pre-glacial drainage lines in the vicinity of Wooster as proposed by Todd. Depth to bed rock obtained from well records are indicated. The heavy dotted line, circumscribed about Wooster, represents bed rock too near the surface for the stream to have passed in that direction.

of elegant Coal Measure sandstone; and 1¾ miles north of it across Apple Creek valley, on a terrace of which is located South and East Wooster, Wooster University is planted on a hill of naked Waverly shale 522 feet above Lake Erie. Madison Hill has about the same elevation, and between them, but near 200 feet below them, sparkles the crystal water of Apple Creek. No drillings have been made in the center of the channel to the rock floor—so its elevation cannot be proven here—but many drillings have been made for water, which is found in white sand at from 95 to 105 feet. One well was drilled to rock on the side of the channel, at the foot of College Hill and showed

†Ibid., I, p. 52.

120 feet to shale; while six furlongs east, across the Apple Creek, at the foot of Madison Hill, rock was found at 45 feet and the channel runs between these two wells."

There is much evidence to support the conclusion that a large preglacial stream did not flow across the divide from Wooster to Orrville. The narrowing channel between Wooster and Madison Hill, as indicated by rock outcrops and well records would seem to exclude all probability that so large a stream flowed to the northeast toward Orrville. There are no differences in the kind of rock or its resistance to erosion which would account for the channel narrowing so greatly here.

If a continuation of the large valley south of Wooster existed beneath the drift between Wooster and Orrville, it would be reasonable to expect a broad sag to indicate its presence. The existence of all the other large preglacial valleys in this section of Ohio are suggested by broad sags. Although not conclusive by any means, the absence of a sag between Wooster and Orrville along the line indicated by Todd as the probable course of the preglacial river, is not in harmony with the theory that a large stream flowed here.

Referring to Todd's course of the stream from Wooster to Orrville as indicated on the map (Figure 2), Conrey remarks* on page 19, "In an attempt to locate this channel, every ravine on the east side of Apple Creek was examined and found to show rock outcrops except in Section 36, Wayne Township, where Spring Run has cut into a preglacial valley, but the existence of rock outcrops near by, both to the north and south would seem to indicate a channel too narrow for the stream which has been traced past Wooster." "The evidence for a preglacial channel leading to the east through the upland from any point near Honeytown seems negative."

The author has obtained well records and carefully examined the valleys leading into the upland, between Weilersville and Apple Creek Village and found bed rock everywhere so near the surface as to exclude any possibility that the stream crossed here. Likewise, to the north of Wooster the bed rock lies everywhere so near the surface that it is evident that the continuation of the stream was not to the north. The heavy dotted line shown on Figure 2 is so placed to indicate the

*Conrey, G. W. "Geology of Wayne County," Geological Survey of Ohio, Fourth Series, Bulletin 24, 1921.

presence of bed rock too near the surface to allow the passage of the stream. A possible avenue for the escape of the waters has been suggested by way of Apple Creek, to Apple Creek Village, and from there to East Union and Orrville through another old channel. There are several objections to this route. First, as already noted, this valley seems too narrow to have accomodated so large a stream as that indicated by the large valley from Shreve to Wooster. It is apparently the valley of a smaller stream, probably a tributary to the larger stream. The trend of Apple Creek valley is such as to suggest that the trunk stream flowed south instead of east. For a tributary to flow into the main stream at an angle pointing in an upstream direction, (Figure 2) is not normal. Apple Creek valley makes the normal angle such as would be made by a tributary, if the trunk stream flowed in a southwest direction instead of northeast as suggested by Todd. Furthermore, it must be admitted that although possible it does not appear to be a reasonable conclusion to assume that the stream would make such an unnatural bend to the south to get to Orrville. The most significant objection, amounting to proof that the stream did not take this round-a-bout route is revealed by well records obtained by the writer. In Section 7, East Union Township and Section 12, Wooster Township, there are numerous oil wells which extend in a narrow belt, in a northeast-southwest direction across Apple Creek. These wells are so located in the valley and on the upland on both sides, as to make possible a cross-section on the bed rock of the old drift-filled preglacial channel. On the upland in Section 12, Wooster Township, the depth to bed rock is only 30 to 40 feet. Farther east, in the same section, it increases to 133 feet. In the valley, near the stream, one well reveals a depth of only 79 feet to bed rock. In Section 7, East Union Township, the well records going from west to east, are respectively, 118, 160, 198, 227, 245, 75 and 36 feet. These records indicate a considerable distance to bed rock and are understandable when one makes allowance for the glacial drift which is thicker on both sides of the valley, on the sides of the stream, where it has not been removed by stream action. The well-head elevation is the important factor to be taken into account. The depths of 227 and 245 feet are not so impressive when we realize that the well-head elevations are 1020 and 1040 feet A. T., respectively, an altitude much above that of the broad valley south of

Wooster, where the elevation is only 844 feet A. T. The greatest depth to bed rock, obtained in the valley south of Wooster is 206 feet. The altitude of the bed-rock floor is therefore 638 feet A. T. The elevations of Apple Creek valley in Section 7 and 12, East Union and Wooster Townships respectively, range from 940 to 960 feet A. T. When the well-head elevations are taken into account we find that the bed-rock floor here cannot be less than 790 feet A. T. This is 152 feet higher than the bed-rock floor in the broad valley south

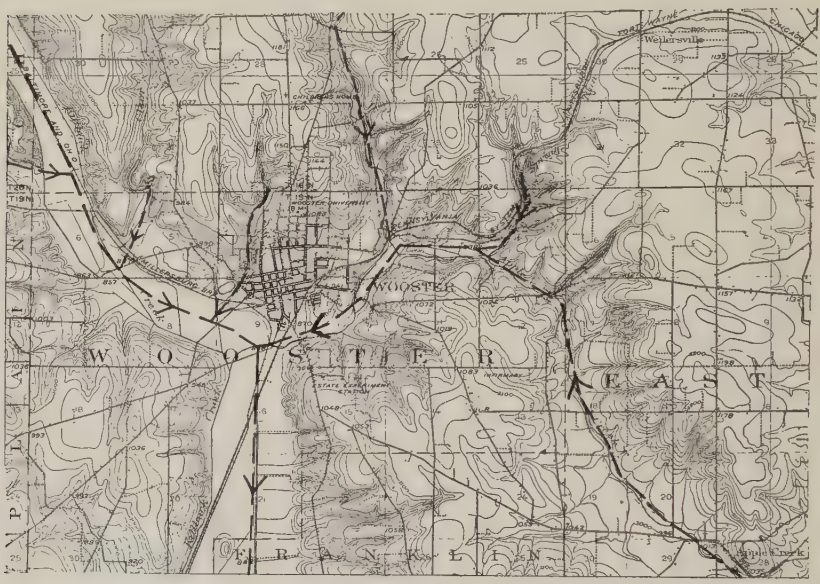

Fig. 3. Pre-glacial drainage lines in the vicinity of Wooster according to the observations of the writer.

of Wooster. Hence it seems impossible that the stream flowed southward by way of the old valley now occupied by Apple Creek.

There is no escape from the conclusion that if the drainage in preglacial time was not north from Wooster and Orrville it must have been south, for that is the only avenue of escape for the waters. The map, (Figure 3) indicates the probable preglacial drainage lines according to the writer's knowledge of the region. It is expected to carry on the investigation still farther with the expectation of offering solutions for the drainage problems to the west and south.

THE ALIMENTARY TRACT OF *PHANAEUS VINDEX* MACL. (SCARABAEIDÆ).*

EDWARD MAJOR BECTON, JR.

INTRODUCTION.

While on a collecting trip to Crane Hollow which is ten miles west of Logan, Ohio, the author noticed the green dung-beetle Phanaeus vindex MacL., was quite abundant in an upland sheep pasture near the Hollow. Upon the suggestion of Dr. C. H. Kennedy the writer spent the day collecting these beetles. The Scarabs were brought back to Columbus alive. They were killed with potassium cyanide, immediately placed in Kahle's Fixative solution and left for two days. The insects were then transferred to 70% alcohol in which they remained from May until fall.

ACKNOWLEDGMENTS.

The author wishes to acknowledge his appreciation to Dr. C. H. Kennedy at whose suggestion and under whose direction the work was carried on. His Lecture Notes and an unpublished thesis, "On the Alimentary Canal of *Megilla fuscilabris*," by Mr. B. J. Landis, have been available for consultation.

Gross Structure of the Alimentary Tract.

The alimentary tract of *Phanaeus vindex* MacL. or *P. carnifex* L. (Scarabaeidæ) is a much coiled though relatively simple structure. In common with most dung-feeding insects the tube is of great length, averaging a little less than eight times that of the body. There are three distinct divisions of the tract; the oesophagus or fore-intestine, the stomach or mid-intestine (mesenteron), the hind-intestine (proctodeum).

The head is flattened so that the front and clypeus extend forward, forming a semicircle as illustrated in Fig. 1. The mouth, which is ventral, is approximately one-third the head length posterior to the front margin.

The buccal cavity is continuous with the pharnyx. The latter converges into the oesophagus, which is a straight, narrow, thin-walled

*A thesis presented for the degree of Master of Science.

tube lying along the mid-line of the body. The posterior limit of the oesophagus is just within the thorax and is marked by the oesophagal valve which separates it from the mid-intestine. No crop or gizzard is present.

The mid-intestine is somewhat larger than the oesophagus and is covered with numerous crypts or papillæ. It continues along the mid-body line until the abdominal cavity is reached. Here the tube begins to coil, making in all nine complete rings of varying circumferences. In Fig. 1 the intestine consists of eight equal coils placed outside the body cavity. To show the length and structure of the intestine it was necessary to be diagramatic in this one instance. The mid-intestine is by far the largest part of the tract, for it averages six and three-fourths times the body length. Just posterior to the oesophageal valve the intestine is often slightly distended but is otherwise of uniform circumference throughout its length.

The four Malpighian tubules arise at the posterior end of fore-intestine. These form a mat of twisted tubes around and in loops of hind-intestine. Following these is a band-like constriction, the pyloric valve. The canal then widens and forms several bends under the dorsal wall of the abdomen. The rectum precedes the anus and appears as a decided enlargement of the hind-intestine. (Fig. 1).

Both fore and hind-intestines are directly attached to the body wall, due to their origin as ectodermal invaginations. The anterior portion of the oesophagus is also supported by fine strands of muscle or connective tissue attached in the head. The mid-intestine lies between the large wing muscles and apparently has no actual supporting tissue. The canal rests free in the abdomen but may be partially held in place by the sac-like tracheæ surrounding it.

The following discussion will deal with the histological structure of the canal, beginning at the anterior end.

The Histology of the Alimentary Canal.

THE PHARYNX.

The pharynx has a heavy chitinous lining which bears short, backward-projecting spines scattered over the surface. The structure is otherwise similar to the oesophagus.

THE OESOPHAGUS.

The intima of the oesophagus is continuous with the cuticula of the body wall and extends the entire length of the fore-intestine, ending in the oesophageal valve. In the anterior portion of the tube it breaks into a series of longitudinal folds which separate preceding the valve. There are no spines in the oesophagus. The primary cuticula is very thin and stains dark with Delafield's Haematoxylin, while the secondary cuticula is thick and almost transparent. The epithelium is composed of a thin layer of cells whose walls are very indistinct, probably due to the fixative (Fig. 2 and 4). There was no apparent basement membrane.

A layer of thin longitudinal muscle strands cover the epithelium. These extend from the anterior end to the region of the valve, where some emerge and continue along the mid-intestine. Due to the strands' interweaving, no long pieces appear in the longitudinal sections (Fig. 2 and 4). Around the longitudinal muscles is a layer of circular muscles which varies in thickness. Toward the oesophageal valve the muscles become more numerous.

Fragments of a peritoneal membrane are found along the oesophagus, indicating that this part of the tube is probably surrounded by it. The membrane is very thin with large, flat nuclei in it. The cell walls are not distinguishable.

OESOPHAGEAL VALVE.

The oesophageal valve divides the oesophagus from the mid-intestine. At this point the mid-intestine and oesophagus seem to have telescoped—the mid-intestine pushing out over the oesophagus, forcing the oesophagus inward, thus partially closing the canal. The narrow epithelium of the oesophagus, in a longitudinal section is bent back to form an S. At the S the layer is somewhat thicker than in other sections and the nuclei are larger. Both divisions of the cuticula continue into the second loop. Outside the epithelium is a dense layer of circular muscle strands. Longitudinal muscles appear as isolated bundles beyond these strands. (Fig. 4).

TRANSITION FROM OESOPHAGUS TO MID-INTESTINE.

The transition of the epithelium of the oesophagus to the columnar type epithelium of endodermal origin is gradual in respect to the change in shape and size. The intima stops abruptly in the interior of the S which denotes a sudden change in the tissue. The first noticeable change in the cells themselves is the appearance of definite cell walls as it continues posteriorly. The cells appear cuboidal and the nuclei round. Gradually the cells lengthen and narrow to the shape typical for the anterior portion of the mid-intestine. The striated border appears and quickly thickens to its average width. In this region the longitudinal muscles come from under the circular and continue along the intestine above the circular muscles.

HISTOLOGY OF THE MID-INTESTINE.

A peritropic membrane is formed in the intestine. This membrane completely encloses the food and continues to surround it throughout the remainder of the canal. Just how or where this membrane is secreted the author was unable to determine.

No intima is present in the mid-intestine.

The epithelium has a striated border lining the lumen. The striæ are very close together and appear to emerge in tufts from each cell. the internal limits of these striæ are not clear. The epithelium is of the columnar type. In the anterior portion they are long, narrow, irregular cells with oblong nuclei. Further along, the cells shorten and thicken with the nuclei becoming oval and granular. Scattered along the basement membrane at the distal portion of the epithelium

are a few small replacement cells or nidi. The writer thinks these cells are non-functional for there is no evidence to show that they develop into full-sized cells.

At intervals, breaking through the muscle layers are large evaginations of the epithelium. These are known as crypts or papillæ, and in many insects they aid in the increase of absorptive surface or produce secretions. In the latter case they are usually connected by tubes to the lumen of the intestine.

A longitudinal section of a crypt shows it to have a group of nuclei forming a cell nest at its distal extremity. No cell walls are visible in this region. Passing inward, elongate cells form leaving an open space along the mid-line of the crypt. Where the crypt passes through the muscle layers this space appears to be choked with irregular shaped cells. The same cells are loosely scattered between the basement membrane and the muscle layers. No opening into the intestine was demonstrated. In the region of the oesophageal valve a ring of large crypts appear. (Figs. 4 and 10.)

The basement membrane is a structureless partition between the epithelium and the muscles. It is thin but shows heavier than the cell walls.

The position of the muscle layers are reversed in the fore and mid-intestine. In the mid-intestine the circular muscles form a single layer next to the basement membrane. The strands of this layer are thin but numerous. The longitudinal muscles consist of narrow, isolated strands continuous with the strands of the fore-intestine. No trace of a peritoneal membrane could be found.

Attached to the striæ and projecting into the lumen of the intestine are small droplets of secretion which stain in Haematoxylin. From this and the fact that none of the epithelial cells show nuclei moving toward or near the striated border; and that there is no indication of the replacement cells acting, the writer concludes that the secretion is probably merocrene.

PYLORIC VALVE.

A thick-walled structure, the pyloric valve, divides the mid-intestine from the hind-intestine. The valve is lined with a thin intima, which begins on the anterior face of the first fold in the valve. The primary and secondary cuticula stain as in the oesophagus. (Fig. 8).

The epithelium consists of a thin layer of tissue similar in appearance to that found in the oesophagus. The nuclei are small, staining dark in Haematoxylin. The cell walls were not discernible. A basement membrane was not found.

Outside the epithelium is a dense layer of circular muscle strands. This layer becomes thicker toward the posterior end of the valve. Isolated strands of longitudinal muscle are found beyond the circular layer.

TRANSITION FROM MID TO HIND-INTESTINE.

In the posterior portion of the mid-intestine the epithelial cells become very elongate as in the anterior portion and from folds. (Fig. 8).

The cells shorten at the Malpighian tubules beyond which is another fold. In this fold many nuclei are present but the cell walls disappear. Posteriorly the fold diminishes into a thin layer in which no cell walls appear. As the hind-intestine is reached the layer gradually widens, cell walls appear and the cells become the elongate type found in the hind-gut.

The muscle layers are continuous with those of the mid-intestine but the longitudinal muscles apparently end at the posterior end of the valve.

HISTOLOGY OF THE HIND-INTESTINE.

The hind-intestine immediately follows the pyloric valve. It is composed of two regions—the ileum and the rectum.

ILEUM.

The ileum includes most of the hind-intestine. It is a tube of more or less equal diameter until the transition area of the rectum is reached. (Fig. 3). The thin intima of the ileum is continuous and identical with that of the pyloric valve.

Columnar cells of ectodermal origin constitute the epithelial layer. These cells have no striated border. The nuclei are large, oval, and stain granular, while the cytoplasm stains uniformly clear. There are longitudinal grooves in the epithelium, thus all the cells are not of equal height or length. The basement membrane surrounding the epithelium is very pronounced. In places not covered by the muscles it appears as a heavy homogeneous layer.

The circular muscles consist of large, round, isolated, bundles which twist around the tube in a loose spiral. Longitudinal muscles were not found in the region of the ileum nor was there a peritoneal membrane present.

TRANSITION FROM ILEUM TO RECTUM.

The intima gradually thickens due to the widening of the secondary cuticula. The transition of the epithelium is slow from the usual columnar type of the ileum to the flat cells of the rectum. The epithelium produces longitudinal strips or folds which extend along the rectum and project into the lumen of the canal. The basement membrane is continuous from ileum to rectum. Isolated strands of longitudinal muscle appear outside the basement membrane. These strands increase in number toward the rectum. Circular muscles also become more numerous, crossing the longitudinal at right angles.

RECTUM.

The rectum immediately precedes the anus and has the greatest diameter of any part of the canal. (Fig. 7). The intima is heavy due to the thickening of the secondary cuticula. The epithelium is a very thin layer of tissue. Longitudinal folds of this extend far into the lumen of the canal. The nuclei are very small, granular, and oval. The cell walls are not apparent in this layer. The basement membrane is not visible.

Longitudinal muscles are very numerous and closely packed. Where these muscles attach at the anterior end the writer was unable to determine. Several layers of circular muscles are present beyond the longitudinal muscles, the strands of which interlace.

Surrounding the rectum is a thin peritoneal membrane.

In the female beetle attached to the ventral wall of the rectum is the vagina, a portion of which is shown in Fig. 7.

MALPIGHIAN TUBULES.

The four Malpighian tubules are evaginations of the hind-intestine at its anterior limit. Various cross-sections of the tubes show them to be irregular in diameter. The courses of the tubes could not be followed but the author found no evidence to show they were attached except at their origin. (Figs. 5, 6 and 9).

No intima was visible in the tubules. The epithelium is composed of large, irregular cells with large round nuclei. Outside the epithelium is the basement membrane which is continuous with that of the hind-intestine. A layer of connective tissue or muscle surrounds the tubules.

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EXPLANATION OF PLATES.

Plate I.

Fig. 1. A dorsal view of the alimentary canal showing all structures in place except the mid-intestine. The ileum includes all of the hind-intestine save the enlarged posterior part which is the rectum.

Fig. 2. A cross-section of the oesophagus.

Fig. 3. A cross-section of the ileum.

Fig. 4. A longitudinal section of the oesophageal valve. One side only is shown.

Figs. 5 and 6. Cross-section of Malpighian tubules showing variation in size.

Plate II.

Fig. 7. A cross-section of the rectum with a portion of the vagina attached to the ventral surface.

Fig. 8. A longitudinal section of the pyloric valve.

Fig. 9. A longitudinal section of the junction of the mid-intestine and the pyloric valve, showing the entrance of a Malpighian tubule. The tubule is cut at an angle and thus appears closed. C—Portion of crypt.

Fig. 10. A cross-section of the mid-intestine taken midway from its limits.

KEY TO FIGURES.

B. M.—Basement membrane.
C.—Crypt.
C. M.—Circular muscle.
EPI.—Epithelium.
F. T.—Fat tissue.
H. I.—Hind-intestine.
INT.—Intima.
L. M.—Longitudinal muscles.
MALP (MAL) TUB.—Malpighian tubules.
M. I.—Mid-intestine.
NI.—Nidi.
OE.—Oesophagus.
OE. V.—Oesophageal valve.
P. E.—Peritropic membrane.
P. V.—Pyloric valve.
S. B.—Striated border.
T.—Trachea.
VAG.—Vagina.

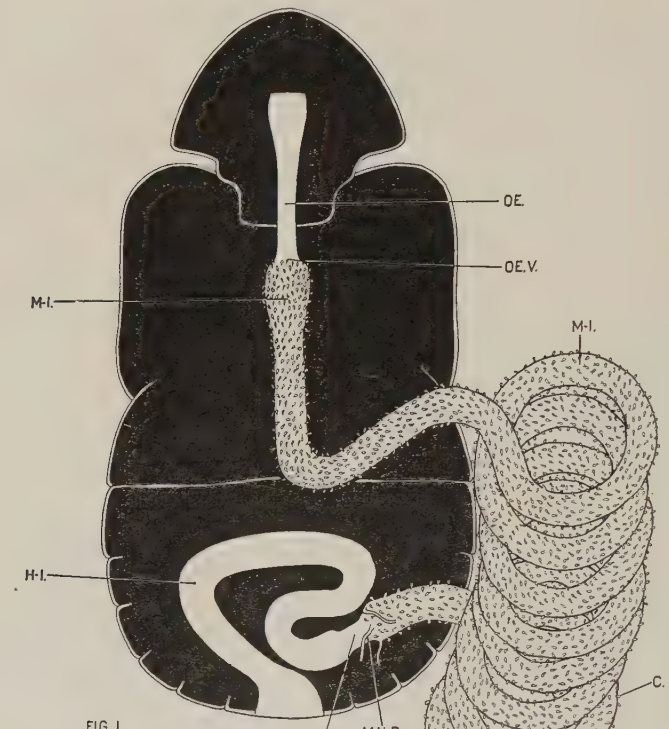


FIG. 1

FIG. 2

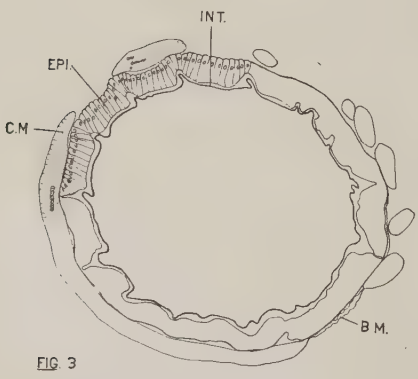


FIG. 3

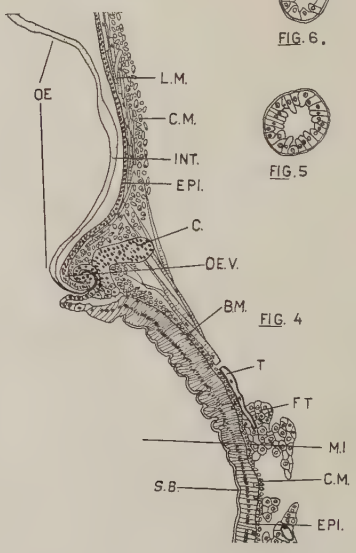


FIG. 4

FIG. 6.

FIG. 5

FIG. 7

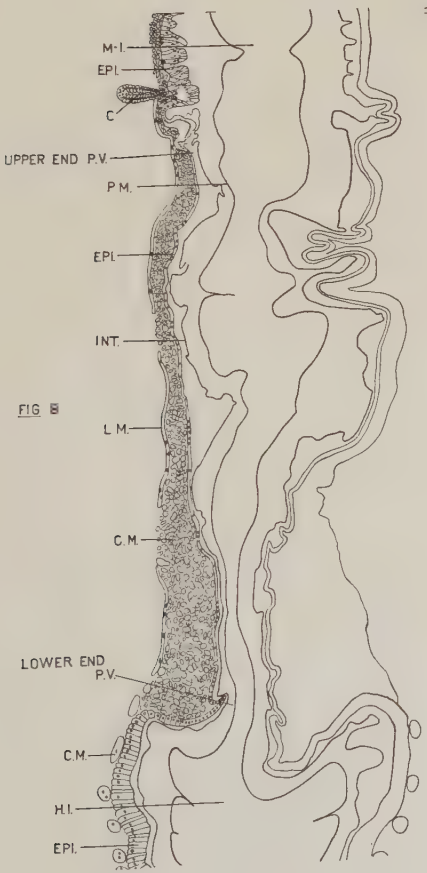


FIG. 8

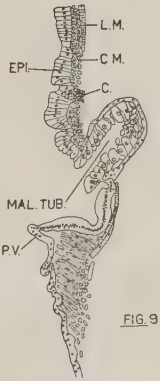


FIG. 9

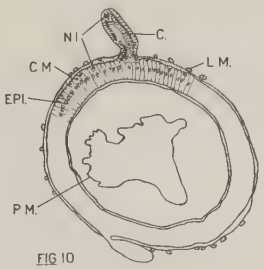


FIG 10

A STUDY OF THE TARSAL STRUCTURES IN CICADELLIDÆ.*

MARY BLANCHE HOWE.

NOTE.—This article includes extracts from a paper prepared some years ago, but which remained unpublished mainly because of the limited openings for publication at the time. It is believed that the parts here given and reference to the table of species, with the figures which are reproduced entire, will furnish a working basis for further studies in related groups. The structures discussed were first figured by the writer in Bulletin 20, Iowa Experiment Station, p. 714, (1893) and figured and described as cited by Miss Howe in 1912. It may be remarked here that while these structures do not seem to offer evidence of generic affinities, they may prove of value in showing affinities of larger or subfamily divisions and that while there is no constant progression in number for the different instars, there is an evident increase of numbers with the age of the insect.

The nomenclature has been revised to agree with the Van Duzee catalogue. The complete thesis is deposited in the library of the Ohio State University.

HERBERT OSBORN.

HISTORICAL REFERENCE.

In Bulletin No. 108, n. s. (1912) U. S. Dept. of Agriculture, Bureau of Entomology: "Leaf Hoppers Affecting Cereals, Grasses and Forage Crops," by Professor Herbert Osborn, Professor of Zoology and Entomology, Ohio State University, p. 76, the following statement appears, "At the end of the first tarsal joint of the hind legs there is a peculiar microscopic spatulate structure that occurs in varying numbers from the newly hatched nymphs to the adult form. In the specimens studied and figured there were for the first instar one, for the second instar two, for the third instar three, for the fourth instar five, and for the adult insect five." (Illustrated p. 74 Ibid.).

At the suggestion of Professor Osborn the work of investigating these structures has been carried through the species included in the following pages. The specimens were supplied from the University or Professor Osborn's collection. These were mounted in balsam, the entire insect where size permitted, the legs only when size precluded, and in that case the insect is either preserved on pin if not mutilated, or if mutilated the insect is preserved in a bottle after legs were removed for study.

I wish to express my very sincere appreciation to Professor Herbert Osborn for his unfailing kindness, interest, advice and the use of his collection of insects and books.

*Extract from a thesis prepared for the degree of Master of Arts, Ohio State University.

General Description.

In describing these structures the term *platella* is used because the terms pallette, plate, and platelet have been applied to other insect structures differing so much from these that it did not seem fitting to apply them in this case.

These platellæ are small spatulate structures usually located at the end of the first and second tarsal segments, although in a few genera, as is shown in the table, they may be found upon the sides of the first tarsal segment.

These structures vary in form and number, even upon right and left leg of the same insect. On one they may be larger and more fully developed than on the other. Sometimes the first tarsal joint will have five and four. Perhaps on the second tarsal joint they may number one and two. In the table prepared I have shown the variations in the different species in the right and left leg in some specimens and whether specimens were male or female, adult or nymph. I have used the following formulæ for convenience in describing each species:

S—Side of first tarsal segment.
T_1—Apex of first tarsal segment.
T_2—Apex of second tarsal segment.

Also in the last column of table I have placed the names of food plants upon which the species was found.

These platellæ arise from a crown of chitinous scales at the apex of the tarsal joint. They are joined solidly and are immovable. The scales and platellæ seem to develop together, as in the immature forms there is no evidence of the scale upon the tarsal joint where it is not yet divided except where the platella is developed. Evidently they are solid, that is there is no air chamber since when the tarsus was placed in alcohol or Xylol there was no air space as there always was in the tarsi and tibiæ until the liquid penetrated the structure. However, I hope later to test this by cross-sections. The platellæ did not break off readily as they were moved about into position in the balsam before putting down the cover glass.

The drawings are flat outline. Stippling is used merely to indicate the thick heavy chitin at base of platellæ and on a few of the heaviest spines. Spines are omitted where they interfered with the view of the platellæ or seemed to cause a confused appearance in the drawings. The drawings are nearly all made with a 16 mm. objective and an 8 ocular. A

TABLE I

SHOWING FORMULÆ OF PLATELLÆ, AND FOOD PLANTS.

	LEFT			RIGHT			Food
	Side	T_1	T_2	Side	T_1	T_2	
Acocephalus nervosus...	5	6	3	5	6	3	Grass, varied, Vegetation.
Acocephalus nervosus...	6	5	3	3	5	2	
Aconura sp.....	.....	4	2	.....	...	...	Coarse Plains Grass.
Agallia sp.....	.....	2	0	.....	...	...	Wheat, Barley, Legumes.
Acinopterus acuminatus.....	.....	4	2	.....	4	2	Grass.
Chlorotettix.....	5	5	4	4	7	4	Grass.
Chlorotettix unicolor....	4	6	3	4	6	4	
Chlorotettix unicolor....	4	6	4	4	6	3	
Chlorotettix sp.....	.....	4	3	.....	...	...	
Cicadella gothica.....	.....	3	2	.....	3	2	Wood Lot.
Cicadula 6-notata.....n	.....	4	...	.....	4	...	Wheat, Grass, Oats, Timothy.
Cicadula 6-notata.....n	.....	4	1	.....	3	1	
Cicadula 6-notata.....n	.....	3	...	.....	3	...	
Cicadula 6-notata.....n	.....	3	...	.....	3	...	
Cicadula 6-notata.....n	.....	4	1	.....	3	1	
Cicadula slossoni.....	.....	3	2	.....	3	2	
Cicadula slossoni.....	.....	3	2	.....	3	2	
Deltocephalus sp.....	.....	2	2	.....	...	...	Wheat.
D. apicatus.....	.....	2	2	.....	2	2	Timothy.
D. apicatus.....	.....	3	1	.....	...	...	
Deltocephalus sp.....	.....	3	2	.....	2	1	
Deltocephalus sp.....	.....	...	...	.....	2	2	
Delt. inimicus.....	.....	6	2	.....	...	...	Blue Grass.
Delt. pascuellus.....	.....	4	2	.....	4	2	
Delt. pascuellus.....	.....	5	1	.....	4	2	
Diedrocephala coccinea..	.....	3	1	.....	3	1	Corn, Wheat, Timothy.
Dreculacephala mollipes	3	3	2	3	3	2	Grasses, Oats, Wheat, Rye, Barley Varied.
Euscelis curtisii.....	.....	...	...	.....	4	2	Timothy, Blue Grass.
Euscelis curtisii.....	.....	5	2	.....	4	4	Wood-lot, Varied.
Euscelis extrusus.....	.....	6	2	.....	...	...	Grass.
Euscelis sp.....	.....	...	...	.....	4	3	
Eutetix cincta.....	.....	3	2	.....	3	2	
E. semi-nudus.....	.....	4	2	.....	...	...	
Gypona 8-lineata var...n	.....	5	1	.....	6	3	Coarse Grass, Varied.
Gypona 8-lineata var...n	.....	5	1	.....	5	1	
Helochara communis....	3	4	2	4	4	2	Bog, Grass, Juncus, Trees.
Idiocerus sp.....	.....	3	2	.....	...	...	
Jassus olitorius.....	.....	2	2	.....	...	...	Varied Shrubbery.
Mesamia vitellina.....	.....	6	3	.....	...	...	Conifers.
Phlepsius sp.....	.....	5	3	.....	6	2	Wood-lot, Oats, Wheat, Grass.
P. fulvidorsum.....	.....	5	2	.....	5	3	Varied.
P. fulvidorsum.....	.....	4	3	.....	5	2	
Platymetopius frontalis..	.....	3	0	.....	3	1	Timothy, Blue Grass, Wood-lot.
Platymetopius frontalis n	.....	5	0	.....	...	...	
Platymetopius frontalis..	.....	4	2	.....	...	...	
Scaphoideus auronitens..	.....	4	2	.....	...	...	Shrubs, Willows, etc.
Scaphoideus immistus...	.....	...	...	.....	5	2	Varied.
Thamnotettix sp.....	.....	...	...	.....	5	4	Timothy, Red-top.
Tham. clitellaris.....	.....	...	...	.....	4	2	Clover, Alfalfa.

few are made with the 4 ocular. This in cases where the tarsi were not contained in the field with the 8 ocular. One *Deltocephalus inimicus* (Figs. 24, 25) with 4 mm. objective shows only the apex of T_1 and T_2 and detail of platellæ.

In the detailed descriptions the species are taken up in the order adopted in Van Duzee's Catalogue.

Description of Structures by Subfamilies.

Subfamily Bythoscopinæ.

In this subfamily the first genus examined was *Idiocerus* (Fig. 1). In the species studied the formula is $T_1 3$, $T_2 2$. These platellæ are elipsoidal and the distal border is narrowed almost to a point, light brown in color, slightly darker than tarsus, rather heavy, flat transversely, but on the perpendicular axis slightly convex to the tarsus. T_1 length .035 mm.; width .015 mm.; T_2 length .03 mm.; width .01 mm. The platellæ arise from a crown of brown chitin which is not so heavy as in some other species.

In *Agallia* the formula for the species studied (Fig. 2) in the specimen examined was $T_1 2$. These are very transparent and delicate, paler yellow than tarsus, flat, spatulate in form. The longer one is almost half the length of the second tarsal joint which is short. They are not set evenly upon the border of the apex of the tarsal joint but the smaller one sets up or back a little from the edge. Each arises from a heavy ring of chitin.

Macropsis and *Bythoscopus* were found to be without platellæ in all the species examined.

Subfamily Cicadellinæ.

Cicadella gothica. The formulæ in this species in the specimens examined were $T_1 3$, $T_2 2$. On T_1 the three platellæ are broadly oval on the distal border, lateral border straight, heavy in texture, set evenly on the apex, slightly convex to tarsus. Length .03 mm.; width .015 mm. On T_2 the two platellæ are set wide apart on the apex. The distal border has more pointed oval sides tapering towards base, dark brown, heavy texture. Length .0275 mm.; width .0125 mm. On both segments the platellæ are slightly darker in color than on the tarsus. (Figs. 3, 4.)

Graphocephala coccinea. (Figs. 5, 6). In this species the formula in the specimen examined is $T_1 3$; $T_2 2$. The platellæ are large, heavy and dark brown, while the tarsus is yellow, and the scales which form the crown of chitin are heavy, long and sharp pointed. The three platellæ on T_1, are similar in form, distal border oval, lateral border straight, flat transversely but slightly convex on the perpendicular axis to the tarsus. Length .04 mm.; width .0125 mm. The platellæ on T_2, are similar to those on T_2 but smaller. Length .03 mm.; width .01 mm.

Subfamily Gyponinæ.

Gypona 8-lineata var *cana*. (Figs. 11, 14). The formulæ for the specimens examined are: left, $T_1 2$, $T_2 2$; right, $T_1 6$, $T_2 3$. These are rather long and slender, tapering towards both ends, flat pale yellow, unicolorous with tarsus, uniform in size and standing perpendicularly on the apex. Length .05 mm.; width .01125 mm. to .015 mm. The platellæ on T_2 so closely resemble those on T_1 in form and arrangement as to require no separate description.

In the nymphal specimens of Gypona (Figs. 13, 14) there are but two tarsal joints. The formula is 5 for T_1 and 1 where T_2 is beginning to divide. These are set at an angle to the apex, tapering to a point at the distal edge and not very uniform in outline. Length .03 mm.; width .01 mm. Segmentation has begun in T_2, and the platella has developed, short, wider at proximal end, tapering to distal border. Length .02 mm. width .01 mm.

Subfamily Jassinæ.

Acocephalus nervosus. (Figs. 15, 16). In this species the formulæ for the specimens examined are S5; $T_1 6$; $T_2 3$; both right and left legs. The first platella on the side of T_1, nearest the proximal end is spatulate and transversely concave, flat in the perpendicular axis, widening from the base to the distal border. The other four on the side are somewhat larger, not so much curved, and tapering a little more at an angle of less than 45° from the body. Each one arises from the center of a heavy chitinous ring. At the apex of T_1, the platellæ are more slender, tapering in at the base, spreading out flat transversely, spatulate, and tapering in at the point, slightly concave from the tarsus; length about half that of the portion of the second tarsus extending below it. These are brownish yellow, unicolorous with tarsus, and arise from a heavy crown of chitin. The platellæ at apex of T_2 are similar to those of T_1. In another specimen (Figs. 17, 18) of *Acocephalus* sp. the formulæ are S3; $T_1 5$; $T_2 2$; for right; S6; $T_1 5$; $T_2 3$; for left. In this specimen the platellæ are all translucent and almost colorless.

Mesamia vitellina. (Fig. 19). The formula for the specimen examined was $T_1 6$; $T_2 3$. On T_1 the first four are slender, quadrate with rounded angles, straight lateral borders presenting a rectangle in form. The others are shorter and wider. These do not stand evenly on the apex. The second one overlaps the first one slightly. They vary in length from the first. Length .05 mm.; width .0125 mm.; the smallest length .03 mm.; width .0125 mm., the shorter ones being wider. On T_2, the platellæ are similar in shape to the first four on T_1. Length .03 mm. to .02 mm.; width .01 mm. on all.

These are pale yellow. The crown of chitin from which they arise is a little deeper yellow. Platellæ are unicolorous with tarsus.

Platymetopius frontalis. (Figs. 20, 21.) In the specimen examined the formulæ vary (see table). On T_1, we have 3, 4, or 5 platellæ. These are quadrate with rounded angles, lateral border straight, set evenly in crown of chitin, flat, a very pale yellow, unicolorous with tarsus, thin and transparent.

Length .03 mm.; width .01 mm. Those on T_2 are broader at distal border and rounded, tapering in to the narrow base, otherwise similar to those on T_1. Length .02 mm.; width .015 mm.

On the one nymph (Figs. 22, 23) examined T_1 had 5 platellæ. These were not uniform as in the mature specimens. The second platella from the outer one was longer than the outer one. The others tapered in to the base and were set irregularly on the apex. This seems a characteristic common to all immature forms. On T_2 the line where division was to take place was visible, and the two large spines were developed but no platella.

Deltocephalus inimicus. (Figs. 24, 25.) This is the species especially described by Professor Herbert Osborn in the Bulletin quoted at the opening of this article. In Deltocephalus the formulæ vary as may be seen from the table. T_12; T_22; T_16; T_22; T_16; T_22 is the formula of D. inimicus in the specimen examined, but this specimen is not fully developed, the third tarsal joint not being separated yet. On T_1 the four outer platellæ have straight lateral borders, tapering in towards the base so that they are slightly narrower at the base. They stand perpendicular and parallel with the apex. The two inner platellæ are transversely convex towards the tarsus and stand at a slight angle towards the body of the tarsus. The platellæ are pale almost colorless, unicolorous with tarsus, at the distal end verging into a light brown at base. The crown of chitin is dark and heavy. Length .015 mm.; width .01 mm. Rounded at distal border and tapering in towards base, about half as wide at base as in the widest part.

Cicadula slossoni (Fig. 74, 75). The formulæ for both male and female are T_13; T_22, both right and left legs. These are a little stouter and darker brown than the nymph forms of *C 6*-notata, but closely resemble them in shape. The two outer on T_2 are straight with distal border drawing slightly towards a point but in no wise spines. Length .02 mm.; width .0050 mm. They arise from a dark brown almost black crown of chitin. In color they agree with the distal ends of tarsal segments which are darker brown than the body of segments. There is no difference in the structure in male and female.

Gnathodus = *Balclutha* was examined and found to be without the platellæ.

Subfamily Typhlocybinæ.

The species of *Empoasea* examined were without platellæ.

Parallel Structures in Other Groups.

In related groups the only structure resembling this is a formation known as a calcar at the base of the tibia in Fulgoridæ. The formation is used in the Keys to Species (See "A Contribution Toward a Monograph of the Homoptera Insects of the Family Delphacidæ" by David L. Crawford of Stanford Univ. Calif., No. 2041, Proc. of U. S. Nat. Museum, Vol. 46, pp. 557-640. Plates 44-49, March 4, 1914) as "a constant and easily appreciated character of identification."

This calcar is a single large movable spine of varying type, as spiniform, tectiform or cultrate. These forms are further modified by the addition of teeth either coarse or fine along the border. They differ from the structure on the tarsal segments of the Jassids in that they are articulate, there is but one, and it is very large in comparison with the platellæ on the tarsal joints of the Jassids. The writer found no comment as to whether this calcar was the same size in nymphal stage as in adult.

In Cercopidæ nothing similar is found but instead a series of flat hairs fringe the tarsal joints, as is figured in illustration (Fig. 76).

Taxonomic Significance.

One question which presented itself in the investigation of these structures on the tarsal joints of Cicadellidæ was whether they might be of specific or generic value or even of use in defining subfamilies. They are present in every subfamily except Typhlocybinæ. In the subfamilies there are such differences within the group, and such likenesses between genera of different subfamilies that the results as a whole are negative.

In Bythoscopinæ two genera have platellæ but in the two the characteristics are very different. In *Idiocerus* they are dark, heavy and pointed, in Agallia they are delicate, rounded, translucent, more like those on Cicadula. Idiocerus seems more nearly related to the next subfamily Cicadellinæ in this respect. *Cicadella gothica* has platellæ heavy and brown; *Graphocephala* heavy but not so dark; *Draeculacephala* heavy but not dark and no longer pointed but quadrate-angular; *Helochara* heavy but lighter in color, more slender, quadrate-angular, and inclining toward Gyponinæ. *Gypona* has platellæ rather long and slender but comparatively large as the entire leg is large. *Acocephalus* in the next subfamily also large and heavy agreeing with the entire leg in that respect. In *Mesamia vitellina* they are more like *Gypona* but have the quadrate angular tip instead of the tapering form of Gypona.

In *Platymetopius frontalis*, the platellæ are short, broad and thinner in texture, and slightly concave transversely, not at all resembling *Mesamia*. In *Deltocephalus* the platellæ are somewhat similar to *Platymetopius* but more curved in outline, and thinner and more delicate in structure. The entire tarsus is not so heavy as those previously discussed. *Euscelis* is somewhat heavier than *Deltocephalus* and a little longer.

In *Eutettix* the tarsi are heavier and the platellæ are much thinner and lighter in structure. They are broad like *Euscelis*. *Aconura* is more like *Helochara* in the Cicadellinæ, quadrately angular but not quite so slender. *Phlepsius* is even more like *Helochara* in outline and of thick heavy structure. *Acinopterus* returns to the broad flat type and closely resembles *Platympopius* although heavier. *Scaphoideus* again is more like *Phlepsius*, long, slender, and it seems ought to come next to it rather than after *Acinopterus;* or else *Acinopterus* should be placed next to *Eutettix*. *Thamnotettix* again returns to the broad flat type, and the platellæ are set somewhat irregularly on the tarsal joint.

Chlorotettix is quite a contrast to *Thamnotettix*. The platellæ are numerous, long, broad, and straight, on the first tarsal joint arranged with regularity, but somewhat irregular on the second tarsal joint.

In *Jassus olitorius* the platellæ are very heavy and dark, much heavier than any other examined, resembling the early members of the series more, being as heavy, tapering more and larger than *Cicadella gothica*, in form and structure more like Idiocerus than any other. *Cicadula*, the last of the group possessing platellæ is characterized by very small delicate structures more nearly resembling those in *Agallia* than any others.

As a whole the variations are so gradual through the series that if one or two genera were changed about in position no definite particular characteristic could be selected as being sufficiently different from others to warrant its use as a character of generic value, and, as was stated at the beginning of this section, would eliminate but one Subfamily, Typhlocybinæ.

Developmental Significance.

Do they indicate age or instar? In *Cicadula 6-notata* a number of nymph forms were examined to determine if the platellæ varied in number with the instar. The youngest nymphs as indicated by wing development had three platellæ on the first tarsal joint, the next oldest had four and the oldest, but still immature forms, had four on first tarsal joint, and one small platella developing on the first tarsal joint where the division was beginning to take place to form the middle segment of the adult tarsus. In the adult specimens *C. slossoni* the first tarsal joint bore three platellæ, the second joint, two.

In the nymph *Gypona* the second tarsal joint was not separated but one platella had developed at the line of separation. The first tarsal joint bore five platellæ. In the adult specimen one leg bore five and two, the other leg bore six and three. This shows that the development may vary in the two legs of one specimen. Similar variation in other species is shown in the table. This appearance of a less number of platellæ in the *Cicadula* and *Gypona* nymph forms adds proof to the observation quoted at the opening of this paper.

Correlation of This Structure With That of the Food Plants.

In an examination of the various food plants upon which the different genera were found to see if there were any hairs or scales or structures of any kind which might seem to demand the development of these platellæ nothing of special significance was observed in pubescence or scales to indicate a special function for the platellæ. The spines and tarsal claws hold them and serve as a lever when they jump or arise from their resting place. There is nothing unless they afford a broader base and more leverage at the instant of flight but the spines extend so much beyond these structures that they would hardly touch a surface which the spines rested upon, unless the spines penetrated among the small hairs, and the platellæ rested on these hairs of the leaves.

Evolution of the Structures.

In studying the development of these structures, comparison with the other members of the group has been made. Fulgoridæ have a single large articulate spine or calcar on the tibia. The distal border of the tarsal joints in Cercopidæ is fringed with flat hairs. (Fig. 76). In Membracidæ there is one thick short heavy scale on the first tarsal joint and then a rather sparse fringe of delicate hairs. At the same time the diameter across the distal border is very much less, in fact the tarsal joint is almost straight. But in none of these is there any appearance of the spatulate plates or platellæ. This structure seems peculiar to the Cicadelldis alone. The shape of the tarsal joints in Cicadellidæ is more like that in Membracidæ. The spines are coarser and stouter.

The difficulty in homologizing these structures with the hairs of the other members of the group is the fact that the platellæ are rigidly attached. So far as evidence goes they are organs which have originated *de novo* in this member of the group. Their absence in certain genera may be either a primitive or a vestigial condition.

As the Typlocybinæ are distinctly specialized forms it is possible that these structures were eliminated in the evolution of this group, or else that the structure developed in the other divisions of the group after Typhlocybinæ separated from the primitive stem.

EXPLANATION OF PLATES.

Abbreviations—P., platella; S., spine; T_1, T_2, T_3, Tarsi, 1, 2, 3.

Plate I.

Fig. 1. Idiocerus, sp. (imago).
Fig. 2. Agallia, sp. (imago).
Fig. 3. Cicadella gothica ♀, (imago). Right.
Fig. 4. Cicadella gothica ♀, (imago). Left.
Fig. 5. Graphocephala coccina ♂, (imago). Left.
Fig. 6. Graphocephala coccinea ♂, (imago). Right.
Fig. 7. Draeculacephala mollipes ♀, (imago). Left.
Fig. 8. Draeculacephala mollipes ♀, (imago). Right.
Fig. 9. Helochara communis ♀, (imago). Left.
Fig. 10. Helochara communis ♀, (imago). Right.

Plate II.

Fig. 11. Gypona 8-lineata var. ♂, (imago). Right.
Fig. 12. Gypona 8-lineata var. ♂, (imago). Left.
Fig. 13. Gypona 8-lineata var. (nymph). Right.
Fig. 14. Gypona 8-lineata var. (nymph). Left.
Fig. 15. Acocephalus nervosus, ♂.
Fig. 16. Acocephalus nervosus, ♂, (imago).
Fig. 17. Acocephalus sp. (imago). Right Leg.
Fig. 19. Mesamia vitellina, (imago).

PLATE III.

Fig. 18. Acocephalus sp. (imago). Left Leg.
Fig. 20. Platymetopius frontalis (imago).
Fig. 21. Platymetopius frontalis (imago).
Fig. 22. Platymetopius, (imago).
Fig. 23. Platymetopius, (nymph).
Figs. 24 and 25. Deltocephalus inimicus.
Fig. 26. Delt. apicatus, (imago). Left Leg.
Fig. 27. Delt. apicatus, (imago). Right Leg.
Fig. 28. Delt. apicatus, ♂, (imago). Right Leg.
Fig. 29. Delt. pascuellus, ♀, (imago). Right Leg.
Fig. 30. Delt. pascuellus, ♀, (imago). Left Leg.
Fig. 31. Delt. pascuellus, ♂, (imago). Left Leg.
Fig. 32. Delt. pascuellus, ♂, (imago). Right Leg.
Fig. 33. Deltocephalus, (imago).
Fig. 34. Deltocephalus, (imago).
Fig. 35. Deltocephalus, (imago).
Fig. 36. Deltocephalus, (imago).

PLATE IV.

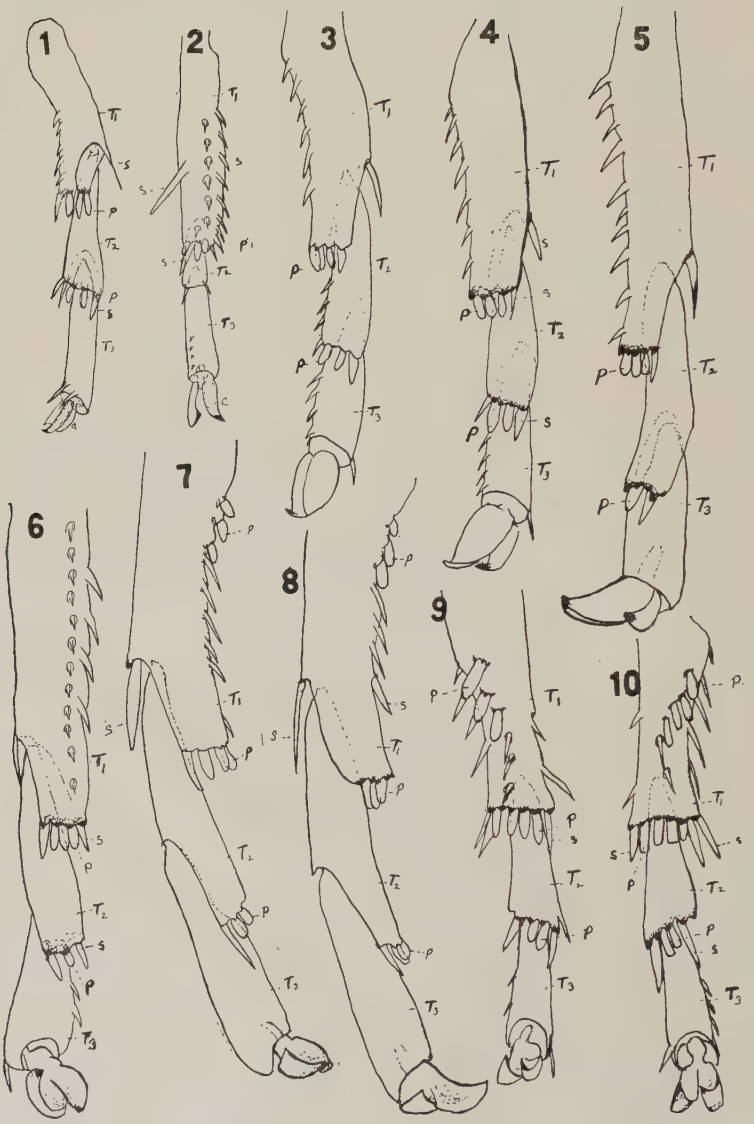
Fig. 37. Euscelis curtisii, (imago).
Fig. 38. Euscelis extrusus, (imago).
Fig. 39. Eutettix cincta, (imago). Right Leg.
Fig. 40. Eutettix cincta, (imago). Left Leg.
Fig. 41. Eutettix semi-nudus ♀, (imago).
Fig. 42. Aconura, ♂, (imago).
Fig. 43. Phlepsius fulvidorsum, (imago). Right Leg.
Fig. 44. Phlepsius fulvidorsum ♂, (imago). Left Leg.
Fig. 45. Phlepsius fulvidorsum, (imago). Left Leg.
Fig. 46. Phlepsius fulvidorsum, (imago). Right Leg.
Fig. 47. Phlepsius sp., (imago). Left Leg.

PLATE V.

Fig. 48. Phlepsius sp., (imago).
Fig. 49. Acinopterus acuminatus, (imago). Left.
Fig. 50. Acinopterus acuminatus, (imago). Right.
Fig. 51. Scaphoides auroniteus, (imago).
Fig. 52. Scaphoideus immistus, (imago).
Fig. 53. Thamnotettix sp., (imago).
Fig. 54. Thamnotettix clitellaris, (imago).
Fig. 55. Chlorotettix unicolor ♂, (imago). Right Leg.
Fig. 56. Chlorotettix unicolor, ♂, (imago). Left Leg.
Fig. 57. Chlorotettix unicolor, ♀, (imago). Left Leg.
Fig. 58. Chlorotettix unicolor, ♀, (imago). Right Leg.
Fig. 59. Chlorotettix unicolor, (imago). Right Leg.
Fig. 60. Chlorotettix tergatus, (imago).

PLATE VI.

Fig. 61. Jassus olitorius.
Figs. 62, 63. Cicadula, (nymph). Right.
Figs. 64, 65. Cicadula, (nymph). Left.
Figs. 66, 67. Cicadula, (nymph). Right.
Figs. 68, 69. Cicadula, (nymph). Right, Left.
Figs. 70, 71. Cicadula, (nymph). Right.
Figs. 72, 73. Cicadula slossoni, ♂, (imago). Right Leg.
Fig. 74. Cicadula slossoni, ♀, (imago). Left Leg.
Fig. 75. Cicadula slossoni, ♀, (imago). Right Leg.
Fig. 76. Cercopidæ. Philaenus lineata, (imago).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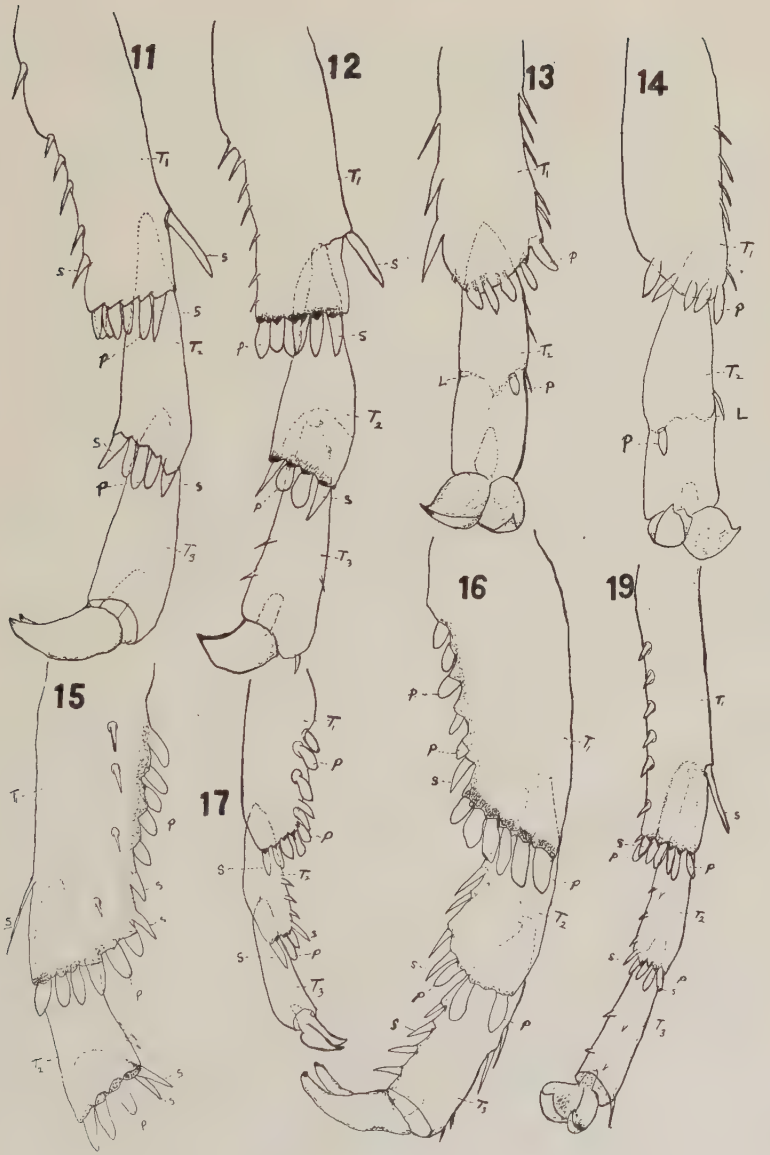
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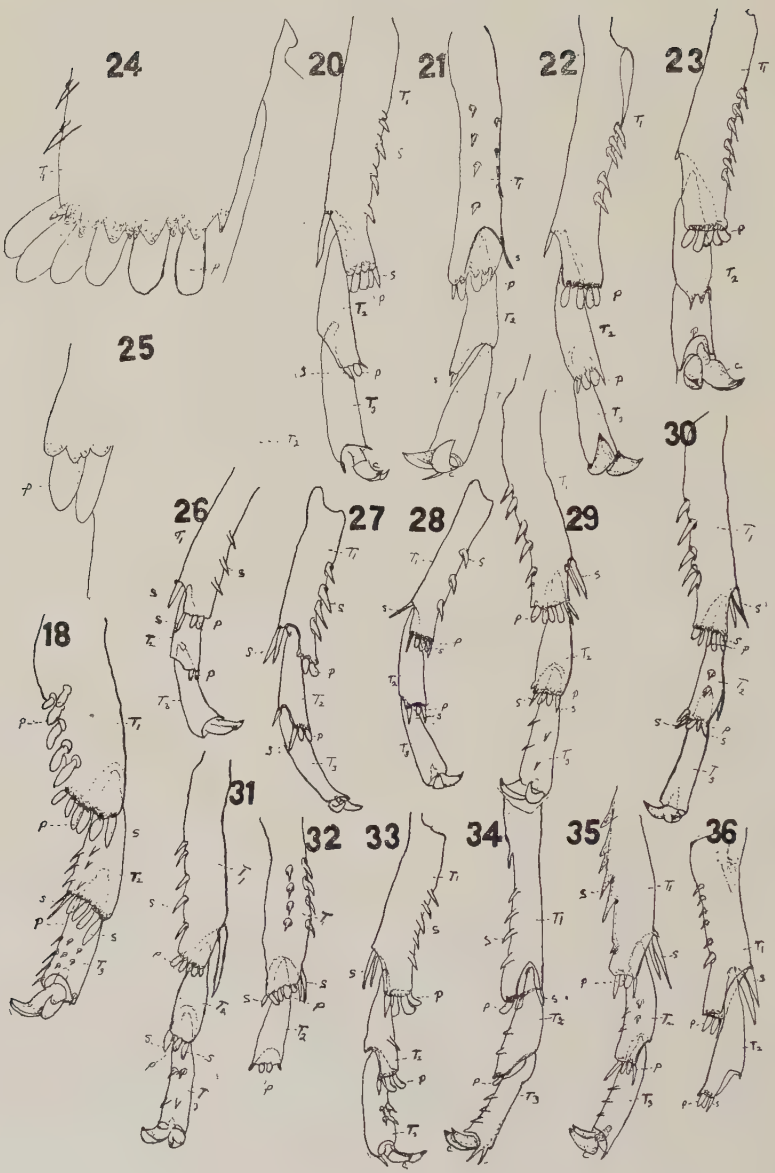
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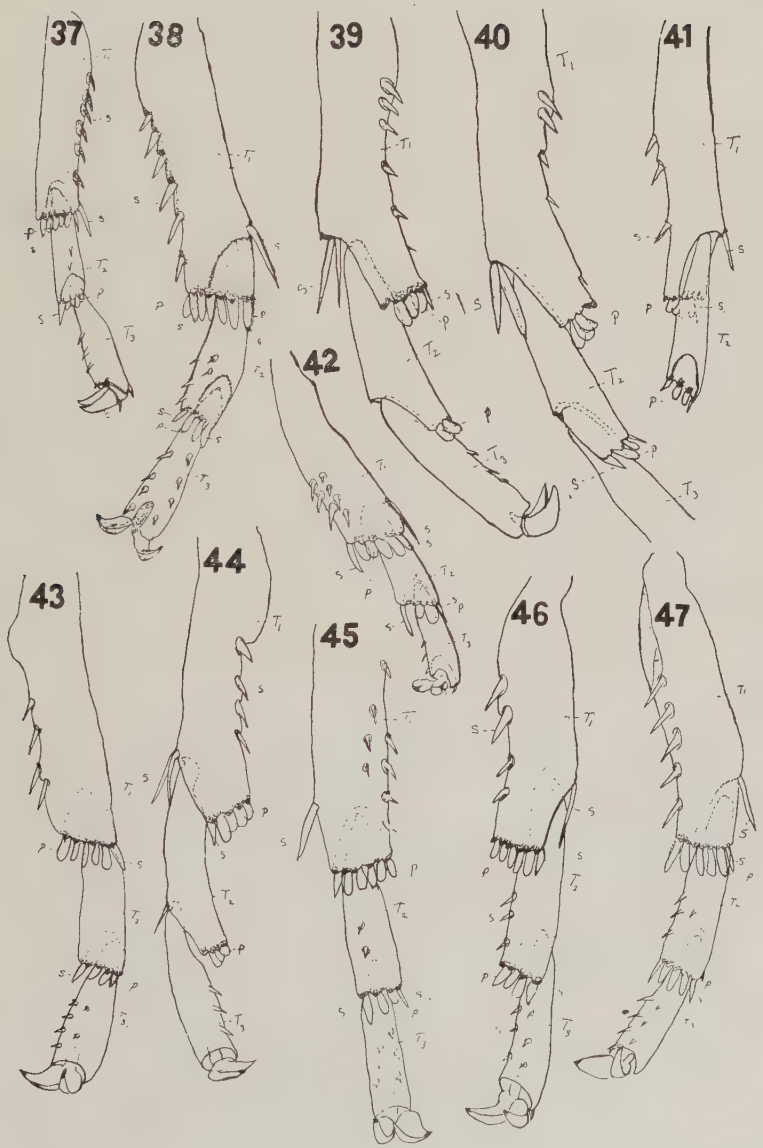
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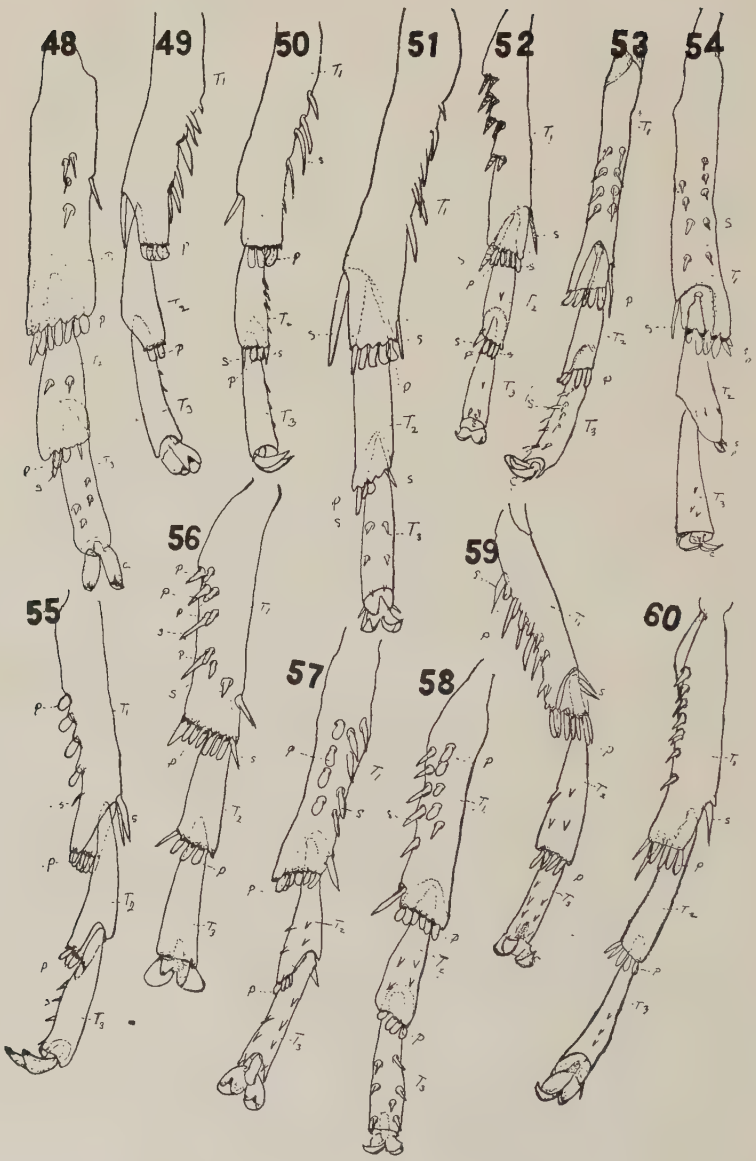
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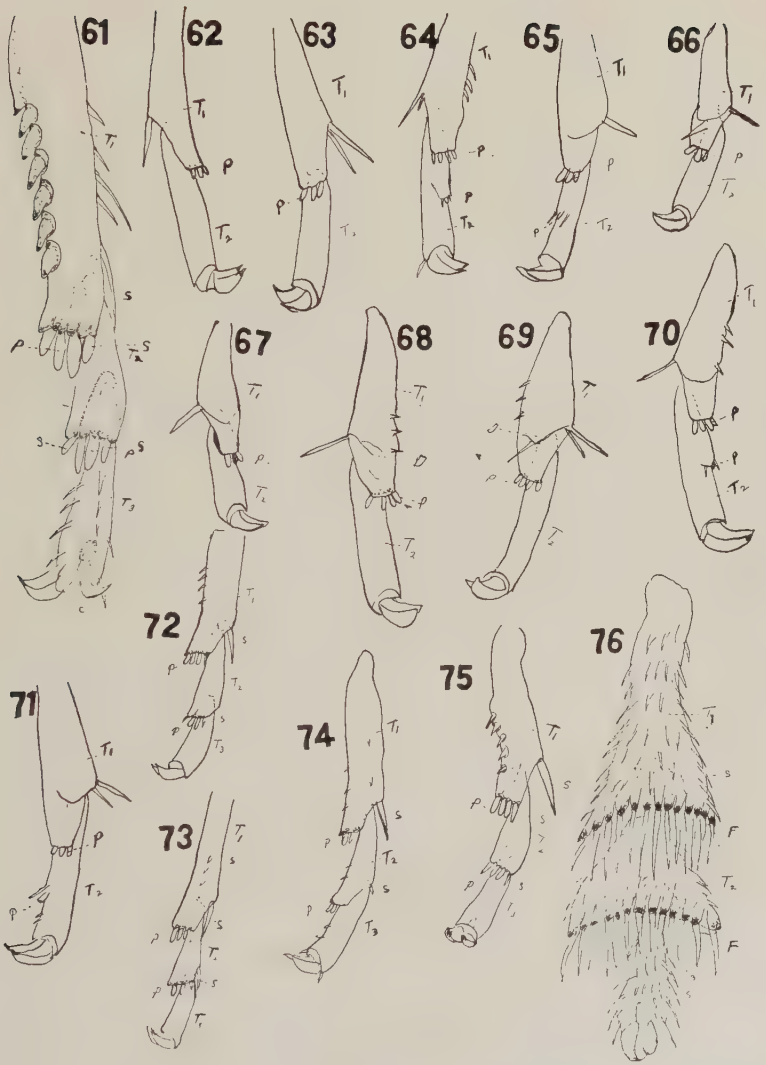
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SUCCESSION IN THE SWAMP FOREST FORMATION IN NORTHERN OHIO.*

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INTRODUCTION.

In descriptions of the deciduous swamp forest formation of eastern North America plant ecologists have generally recognized an elm-ash-soft maple† community. In Northern Ohio this community occurs in the successional series from both marsh and relict bog. In the succession from marsh it follows the willow-poplar association, and in the bog habitats of northeastern Ohio it succeeds the tamarack forest. The swamp forest formation is ultimately invaded and succeeded either by beech-maple of by oak-hickory when the habitat becomes adequately drained through filling or the development of drainage systems. Although the elm-ash-soft maple community has been long recognized, it has usually received but passing mention in the literature. Its composition, local and geographical variants, and its successional or transitional phases are inadequately described.

An attempt to map the forests of northern Ohio in considerable detail‡ led to the necessity of recognizing (1) certain successional or transitional phases of the swamp forest that frequently developed previous to the invasion of beech, hard maple, or white oak, and (2) certain swamp forest communities in which some of the characteristic secondary species of the elm-ash-soft maple community became sufficiently abundant to be classed among the principal dominants. Some of the data obtained are presented in this report partly because they are helpful in interpreting and classifying forest communities often encountered, and partly to suggest conditions and hypotheses that need further investigation.

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†The term soft maple is used in this paper to include both the silver maple (*Acer saccharinum*) and red maple (*Acer rubrum*). The term hard maple includes sugar maple (*Acer saccharum* and *A. saccharum* Rugelii) and black maple (*Acer nigrum*).

‡Sampson, H. C. and Transeau, E. N. Original plant associations as indices to biotic habitats with special reference to the corn borer. Ohio Agr. Exp. Sta. Bul. 429, pp. 152–163, 1928.

A chart showing the approximate habitat range and the order of invasion of trees into the swamp forest formation of northern Ohio is presented as a basis of showing more readily (1) the habitat range of species encountered in the swamp forest, (2) the order of invasion of the swamp forest habitat by the different tree species, (3) the transitional phases of the swamp forest, (4) the variations in relative abundance of individual species, (5) the different forest types encountered in the swamp forest formation, and (6) the relation of present secondary forests to the different phases of the virgin swamp forest.

In order that the reader may have a setting and a glimpse of certain major points that will be developed in this paper the following generalizations are stated at the outset. The commonly recognized elm-ash-soft maple community characteristic of swamp habitats in the Great Lakes region is often correctly designated as an american elm-white ash-red maple association in that these three trees are the dominant species. But in the wetter habitats occupied by the elm-ash-soft maple community, black ash is the species of ash encountered, and in northwestern Ohio silver maple is sometimes more abundant than red maple.

Of much more importance, however, are the two departures dependent upon the order of invasion and upon the variations in relative abundance of the secondary species of the elm-ash-soft maple community.

In the first place the order of invasion of the secondary species is dependent primarily upon drainage conditions. In the elm-black ash-soft maple association pin oak and swamp white oak are the principal secondary species. By the time the drainage is sufficient for white ash to appear as one of the dominants, bur oak and big shellbark hickory also come in as secondary species. With further increase in drainage several other secondary species come in, such as linden, black cherry, shagbark hickory, red and yellow oak, bitternut hickory, and even tulip and walnut. These secondary species are too rare in some localities to appear significant, but in other localities they are sufficiently abundant to attract attention and to suggest transitional phases of the elm-ash-soft maple community as indicated in the chart. The transitional phase characterized by tulip and walnut is not given special mention in the chart, but it is indicated by the length of the horizontal lines in the vertical column representing the red oak-linden transition.

Secondly, and still more important is the fact that some of these secondary species such as oaks, hickories, linden, tulip, and walnut may become so abundant in certain habitats that they are properly classed among the principal dominants of the forest community. In such habitats the expression "elm-ash-soft maple" is obviously a misnomer, and other forest communities corresponding to the transitional phases of the elm-ash-soft maple community mentioned above must be recognized. Terms used to designate these different forest communities are to be considered as tentative until further studies of the swamp forest formation are made. The term swamp forest formation is used in this paper to include the entire successional series of swamp forest communities.

Attention should be called to the fact that the swamp forest formation in northern Ohio is perhaps unexcelled anywhere in the northern and central portions of the Deciduous Forest Formation of North America both in area covered and in the number of tree species represented. It occupies much of the area within the old beach lines of the glacial lakes Maumee, Whittlesey, and Warren. It is the prevailing forest on that part of the old lake bed known as the Black Swamp of northwestern Ohio. On the glaciated area south of the beach lines it continues to be one of the prevailing forest types though seldom occupying large continuous areas. Owing to poor drainage many swamp forest habitats were the last to suffer the encroachment of civilization. Consequently conclusions reached in field surveys were checked by consulting men who knew the virgin forests of certain areas and were able to compare them with the present secondary forests, and with the few relict areas that have been least disturbed.

Of the upland forests of northern Ohio beech-maple is the most extensive and characteristic virgin forest. Of second importance are the white oak-black oak-hickory and the oak-chestnut communities. Other communities occurring locally are oak-chestnut-tulip, the mixed mesophytic forests, white pine, hemlock, beech-maple-hemlock-yellow birch, and big bluestem and bunch grass prairies.

On the old lake bed therefore are areas prevailingly swamp forest interspersed with local areas of beech maple, oak-hickory, or marsh; areas prevailingly beech-maple interspersed with local areas of swamp forest and marsh; and areas prevailingly oak-hickory interspersed with local areas of swamp forest,

marsh, and prairie. The most extensive area of oak-hickory within the old beech lines is in Erie County.

The vegetation on the old beaches differs markedly in passing eastward across the state. In Fulton, Lucas, and Wood Counties White oak-black oak with some hickory is the characteristic forest of beach and sand deposits. In eastern Sandusky County beech and tulip are locally abundant on sand deposits, while in Erie County, oak-chestnut and oak-hickory occupy the sand and gravel deposits. From Berlin Township, Erie County, eastward oak-chestnut and oak-chestnut-tulip are on the dryest sand deposits, and beech-maple becomes one of the principal forests on the beach lines. In Ashtabula County, beech-maple-hemlock occurred locally.

On the morainal drift south of the old beach lines, the prevailing forest is beech-maple interspersed with numerous local areas of swamp forest. Locally areas of oak-hickory similarly interspersed with swamp forests are encountered.

ORIGIN OF THE SWAMP FOREST HABITATS IN NORTHERN OHIO.

The composition of the swamp forest is dependent in part upon previous vegetational history. The physiographic sites in which the swamp forest of northern Ohio has developed are old lake beds, flood-plains, and pre-erosion post-glacial flats. The vegetational history that preceded the swamp forest in each of these habitats may be summarized as follows:

In lake basins: (1) aquatic communities followed by communities characteristic of marshes and of wet prairie, (Jennings[1], Schaffner, *et. al.*[2]), (2) the willow-poplar association of low sand bars and beaches as they emerged (Jennings), and (3) the bog associations (Dachnowski[3], Transeau[4]).

On floodplains: (1) alder and willow-poplar associations, and (2) associations of stream valley bogs characteristic of the Northern Evergreen Forest Formation.

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[1]Jennings, O. E. An Ecological Classification of the Vegetation of Cedar Point. The Ohio Naturalist, 8: 291–340, 1908.

[2]Schaffner, J. H., Jennings, O. E. and Tyler, F. J. Ecological study of Brush Lake. Proc. Ohio State Acad. Sci., 4: 151–165, 1904.

[3]Dachnowski, Alfred. Peat Deposits of Ohio. Bull. 16, Geol. Survey of Ohio, 1912.

[4]Transeau, E. N. On the geographical distribution and ecological relations of the bog plant societies of northern North America. Bot. Gaz., 36: 401–420, 1903.

On certain pre-erosion post-glacial flats the deciduous swamp forest communities undoubtedly succeeded forest communities of the northern evergreen forest, such as spruce, balsam, arbor vitae, birch, and probably hemlock and white pine during the later post-glacial migration.

In addition to the natural successions noted above the influences of man have resulted in secondary successions of swamp forests following the clearing of beech-maple on moist uplands, and of bog shrubs and conifer forests in relict bogs.

The virgin swamp forests of Ohio have, therefore, succeeded the pioneer communities of three different climatic plant formations: (1) the bog heath and the bog conifer forest of the Northern Evergreen Forest Formation, (2) the associations of wet prairies, and (3) the vegetation of marshes characteristic of the Deciduous Forest Formation.

HABITAT RANGE OF THE SWAMP FOREST TREES IN NORTHERN OHIO, AND THE ORDER IN WHICH THEY INVADE THE SWAMP FOREST HABITAT.

Owing to the great number of tree species in the swamp forest a fairly definite knowledge of their individual distribution with respect to certain environmental factors is a valuable aid in recognizing the successional phases, and the variations in composition of different swamp forest communities. The accompanying chart made to illustrate certain facts of the behavior of trees as observed in the swamp forest formation of northern Ohio shows the relative distribution of the different swamp forest trees with respect to the combined effects of all the factors of the natural habitat, but it will be considered at first only to show (1) the approximate habitat range of each species that invades the swamp forest in northern Ohio, and (2) the relative order of the invasion of trees into the swamp forest habitat. The chart will be referred to later to illustrate the transitional phases of the elm-ash-soft maple community, the variations in relative abundance of the different species, and the consequent forest types of the swamp forest formation.

The horizontal lines in the chart indicate the approximate habitat range for each species. The habitat range was obtained in the field by using certain plant associations as habitat indices. The different species were first listed according to

Chart showing the approximate habitat range - horizontal lines - and the order of invasion of trees into the Swamp Forest Formation of northern Ohio. The pioneer shrub and tree communities of marshes and bogs which should appear on the extreme right of the chart are omitted. The relative abundance of species - when present - in the different phases of the plant communities cited in the chart is indicated by the following symbols: a = abundant, c = common, f = frequent, o = occasional, r = rare.

Species	Oak-Chestnut Community	Mixed-Mesophytic Community	Beech-Maple Association	Phases of the Elm-Ash-Soft Maple Community		
				Red Oak-Linden Transition	Bur Oak-Big Shell-bark Hickory Transition	Elm-Black Ash-Soft Maple Association
Acer saccharum Sugar Maple		r-a	f-a			
Quercus alba White Oak	r-a	r-a	r-c			
Fagus grandifolia Beech		r-a	c-a			
Magnolia acuminata Cucumber Tree	r-f	r-a	r-f	r-f		
Juglans nigra Black Walnut	r-f	r-c	r-o	r-a		
Juglans cinerea White Walnut	r-o	f-c	r-o	r-c		
Liriodendron tulipifera Tulip Tree	r-a	f-a	r-o	r-a		
Ostrya virginiana Hop Hornbeam	r-f	r-f	r-f	r-c		
Carya cordiformis Bitternut Hickory	r-f	r-f	r-f	r-c		
Quercus Muhlenbergii Yellow Oak	r-f	r-c	r-f	r-c		
Quercus rubra Red Oak	r-f	r-a	r-c	f-a		
Cornus florida Flowering Dogwood	f-a	o-f	r-f	o-f		
Carya ovata Shag-bark Hickory	r-o	o-f	o-c	f-a		
Morus rubra Red Mulberry	r-f	r-f	r-o	r-f		
Prunus serotina Black cherry	r-f	r-f	r-f	r-f		
Tilia americana Linden, Basswood	r-f	r-o	r-o	r-a		
Ulmus fulva Red Elm	r-f	r-o	r-f	r-c		
Gleditsia triacanthos Honey Locust			...	r-f	r-f	
Aesculus glabra Buckeye			..	r-f	r-f	
Quercus macrocarpa Bur Oak				r-a	r-a	
Carya laciniosa Big Shell-bark Hickory			...	r-a	r-a	
Carpinus caroliniana Blue Beech	r-o	r-f	r-f	f-o	f-c	
Fraxinus americana White Ash	r-c	r-a	r-c	r-a	c-a	
Platanus occidentalis Sycamore				r-f	r-f	r-f
Quercus palustris Pin Oak				r-f	r-o	r-a
Quercus bicolor Swamp White Oak				r-f	r-c	r-a
Nyssa sylvatica Sour Gum	r-f	r-f	r	r-c	r-o	r-a
Ulmus americana White Elm		r-f	r-c	c-a	c-a	c-a
Betula lutea Yellow Birch			r-f	r-f	r-c	r-a
Acer rubrum Red Maple	f-a	f-a	r-c	f-a	f-a	f-a
Acer saccharinum Silver Maple				r-a	r-a	r-a
Fraxinus nigra Black Ash				r-c	r-a	r-a
Populus deltoides Cottonwood				r-o	r-f	r-a

their occurrence or absence in certain plant associations known to represent different degrees of moisture and shade in the habitat. In northern Ohio, the oak-chestnut association* represents the dryest habitats, the willow-poplar association represents the wettest tree habitats, while the beech-maple association represents an intermediate condition of moisture and a maximum of shade. All tree habitats too wet for beech-maple but sufficiently drained for willow-poplar were considered as swamp forest habitats. Within each plant association a moisture gradient may also be recognized partly by the presence or absence of certain species and by the degree of exposure and of drainage associated with the topography and the composition of the soil.

The order of invasion of the trees into the swamp forest habitats is shown on the right side of the chart reading from the bottom of the page upward. The first nine trees at the bottom of the chart are shown extending to the limits of the chart on the right, since all of them invade either the pioneer willow-poplar or the tamarack forest neither of which are included in the chart, but may be assumed by the reader as placed to the right of the chart presented.

After the general habitat range of species with respect to plant associations was obtained, slope and the elevation of low ridges and knolls were then used as an index to the soil moisture gradient within the swamp forest habitat. To one unaccustomed to a flat landscape much of the old lake bed in Northern Ohio at first appears to be level. Closer observation and measurements, however, often show an abundance of low ridges and knolls with gentle slopes of but a few feet per mile. These rather slight differences in topography and consequent differences in surface drainage are reflected in the distribution of tree species. Many of these ridges are but a few inches to a few feet in height but often afford sufficient surface drainage for beech-maple or oak-hickory. On others different phases of the swamp forest are encountered. Internal drainage due to differences in soils was not measured, but soil differences, such as differences in amount of sand, muck, loam, and heavy clay, that could be readily recognized were noted. These marked differences in soils—with some exceptions for sand—appeared

*The oak-chestnut community as represented in the chart includes both the oak-chestnut association and the oak-chestnut-tulip association.

to have relatively little effect upon the *order of invasion* of wet habitats by most of the tree species. Variations in drainage on different areas of the same soil type may be great enough to encompass the whole order of invasion shown in the chart from the elm-black ash-soft maple association to the beech maple association. Furthermore the order of invasion of swamp forests by the principal tree species has been found to be consistent for hundreds of swamp habitats in central and northern Ohio and consequently upon many different soil types. As a result of the above observations, and since soil surveys of several counties in northern Ohio are now in various stages of completion it seemed advisable to postpone detailed studies of the effects of soil types until soil maps are available. Soil maps of Lake and of Sandusky County are now available, and a brief statement of the soil types of northern Ohio by Conrey* is also available.

Briefly, the order of invasion of the elm-ash-soft maple community by different species as drainage conditions increase was arrived at in the field (1) by listing the different species in the order of their invasion as one ascended a gentle slope from the edge of a marsh or lake or from the center of a depression within the swamp forest, (2) by comparing the distribution of species on adjacent low knolls and ridges of slightly different elevation, but of similar soils, and (3) by comparing the distribution of species on gentle slopes of similar soils, but varying in grade from slopes of one or two feet per mile to several feet per mile.

Owing to the great number of species involved and to the high degree of sensitiveness of the trees to slight changes in drainage, consistent data for all species may be expected only when very gentle and uniform slopes are studied. If the slope is abrupt, sufficient space between critical moisture conditions is not available for a definite zonal grouping of all of the species and the order of invasion is obscured. Perhaps the most irregular conditions are encountered in swamp forests in which the area is dotted with numerous small elevations just large enough to support one or a few mesophytic trees. Any one of several mesophytic trees may occur on the different individual knolls resulting in a forest as a whole that is composed of a

*Conrey, G. W. Soil fertility and soil types as indices to biotic habitats. Ohio Agr. Exp. Sta. Bul. 429, pp. 163–168, 1928.

mixture of swamp and upland trees; a mixture that might readily be confused with the mixed mesophytic community.

Elevation above the lake may be ignored, since the angle of the slopes is more important than absolute elevation. In many swamp forest habitats an abrupt elevation of seven to ten inches gives sufficient local drainage for beech-maple or oak-hickory. On the other hand a slope of three or four feet per mile may lead to an elevation of several feet above the lowest depression yet not be sufficiently drained for beech-maple. Consequently when drainage conditions and tree distribution on low knolls and ridges of slight differences in elevation are compared these elevated areas should be near one another, and both slope and kind of soil should be considered.

Locally, knolls of a few yards or a few rods in extent may be so abundant in a swamp habitat as to permit the development of mosaic forests consisting of a continuous swamp forest dotted with small island-like groves of forest types characteristic of better drained areas. The knolls may be composed of sand or of loams.

The order of invasion of the species into the swamp forest as shown to the right of the beech-maple in the chart is dependent upon their endurance of poor drainage or lack of soil aeration. The dropping out of several of these species and the decreased abundance of others when the habitat becomes better drained and is invaded by beech and hard maple is apparently the result of starvation in the dense shade of the latter species, since many of the swamp forest species grow abundantly as secondary forests in these habitats when beech-maple has been removed by clearing or when light is allowed to penetrate the forest canopy by the removal of one of the older trees. The order of dropping out of species as shown to the left of the beech-maple in the chart is dependent upon their endurance of desiccation. It appears that the major controlling factors of the external environment are the combined effects of light, moisture gradient, and soil aeration.

The data in the chart are based upon hundreds of field observations in the least disturbed areas now available. All of the species recorded were not sufficiently abundant in single habitats to determine their order of endurance of poor drainage. Hence each species had to be checked against another time after time in numerous habitats until the order of the whole series was determined. Most attention was given to the

limitations of species considered most significant for the region. The rare occurrence of some of the secondary species in all habitats leaves some doubt of the accuracy of the limitations indicated for them in the chart. A few secondary species are omitted from the chart, but are listed in the body of the paper. The limits of the habitat range indicated on the left side of the chart are based upon fewer data than those on the right.

While the chart is subject to refinement by further observation, by physical determinations of the soil moisture gradient at different seasons, and by experimental tests, it is sufficiently accurate to furnish a basis for the interpretation of the successional or transitional phases of the swamp forest in northern Ohio, and also for certain variations in both virgin and secondary forests.

SUCCESSIONAL OR TRANSITIONAL PHASES OF THE ELM-ASH SOFT MAPLE COMMUNITY.

In swamp habitats where the increase in drainage and soil aeration is very gradual certain successional phases of the elm-ash-soft maple community become evident. In the wettest habitats it is an *Ulmus americana—Fraxinus nigra—Acer rubrum* or *Acer saccharinum* swamp forest community. The secondary species when present in this first phase are sour gum, yellow birch, swamp white oak, pin oak, sycamore, cottonwood, black willow (*Salix nigra*), peach-leaved willow (*Salix amygdaloides*), and trembling aspen (*Populus tremuloides*).

As already pointed out in the introduction, transitional phases of the elm-ash-soft maple community may develop as a result of the order of invasion of its secondary species. Hence a second phase of the elm-ash-soft maple community is recognized when sufficient drainage exists for the entrance of white ash, big shell bark hickory, and bur oak apparently in the order named. There appears to be little difference in the endurance of poor drainage by these three species in natural habitats. Even with the entrance of these species the swamp forest usually remains an elm-ash-soft maple forest and is correctly designated the *Ulmus americana—Fraxinus americana—Acer rubrum* association, though in certain habitats the oaks and hickory also become prominent species. In secondary forests the prominence of oaks and hickory is not unusual. This phase of the swamp forest occupies a sufficient area of

gentle slopes in northwestern Ohio to deserve recognition. For convenience of reference this phase of the swamp forest may be designated the bur oak-big shellbark hickory transition, with the understanding that the name merely refers to the fact that drainage has become sufficient for these two species.

Certain other species also come into this phase of the swamp forest. Carpinus is usually present. Buckeye, honey locust, box elder (*Acer negundo*) and hackberry (*Celtis occidentalis*) are more infrequent in occurrence.

Still a third phase of the elm-ash-soft maple forest becomes evident when increased drainage has made possible the entrance of red elm, linden, cherry, mulberry, shagbark hickory, flowering dogwood, red oak, yellow oak, bitternut hickory, and hop hornbeam. Even with the entrance of these trees elm may continue to be the most abundant tree and many communities may be appropriately designated an elm-ash-soft-maple community or association. But the large number of species now present makes possible several variations in composition and, as will be shown later, in certain habitats the oaks and hickories also become prominent. Perhaps the most convenient name for this phase of the elm-ash-soft maple community is the red-oak-linden transition, with the understanding that the name does not necessarily refer to the prominence of these species but to the fact that drainage has become sufficient for them.

Additional species that may be found in this phase of the swamp forest are green ash (*Fraxinus lanceolata*), blue ash (*Fraxinus quadrangulata*), red ash (*Fraxinus pennsylvanica*), Kentucky coffee tree (*Gymnocladus diovica*), mockernut hickory (*Carya alba*), and fire cherry (*Prunus pennsylvanica*). In northeastern Ohio hemlock occurs sometimes as a relict in this phase of the swamp forest.

Still a fourth phase of the elm-ash-soft maple community sometimes becomes evident before invasion by beech, hard maple, or white oak. Its existence is dependent upon the entrance of tulip, white and black walnut, and magnolia into the swamp forest slightly before the invasion and dominance by beech. In this transitional phase of the swamp forest may be found individuals of all of the species named above, yet in many habitats elm-ash and soft maple may be the most prominent trees. In keeping with the terminology already used for the other phases of the swamp forest, this final phase may be designated the tulip-walnut transition.

The last three phases of the swamp forest are not always evident in a particular site. They may be evident on low ridges of slightly different elevation, in shallow depressions of different depths and degrees of drainage, and on very gentle slopes, but if the slope from the swamp forest to the upland forest is noticeably abrupt the assortment of the above species in the narrow fringe of forest at the edge of the swamp is not evident. Neither is it evident in swamp forests dotted with, numerous knob-like elevations upon which only one or two of the more mesophytic trees may grow.

While the above observations were made mainly upon swamp forest habitats that originated in marshes additional observations show that similar conditions exist in swamp forests originating in conifer bogs, and on flood plains. In fact the mixed forests on some of the flood plains of this region are more readily comprehended in the light of the facts stated above. These transitional phases may occur either where beech-maple or where oak-hickory is the upland forest. They also occur in the very numerous local swamp forest habitats in the beech-maple or oak-hickory forests on the glacial morain south of the old beach lines. Here the relative depth and drainage of the different depressions are at once characterized by the one or the other of the above transitional phases of the elm-soft-maple community, or by the corresponding forest community to be described under the following topic.

SWAMP FOREST COMMUNITIES RESULTING FROM VARIATIONS IN THE RELATIVE ABUNDANCE OF THE SECONDARY SPECIES OF THE ELM-ASH-SOFT MAPLE COMMUNITY.

As already pointed out the elm-ash-soft maple community may include an elm-black ash-red or silver maple association and the succeeding elm-white ash-red maple association. The latter association may further be considered in certain habitats as consisting of at least three transitional phases depending upon the order of invasion of its prominent secondary species. We come now to a brief consideration of a more fundamental modification of this association brought about by the relative increase in abundance of some of the secondary species that places them among the dominants of certain habitats. The resultant swamp forest communities correspond, in the suc-

cessional series, to the transitional phases of the elm-ash-soft maple community already described, but they are not dominated solely by elm, ash, and maple. In fact some of the secondary species may be more abundant than either ash, maple, or elm.

Attention is again called to the chart in which the relative abundance of species in different habitats is indicated by the following symbols: a = abundant, c = common, f = frequent, o = occasional, r = rare to absent. Two letters are used for each species since a considerable variation in the relative abundance of individual species is found when hundreds of observations are made. The letters refer to the relative abundance of the species in the virgin forests.

In the vertical column representing the elm-black ash-soft maple association yellow birch, pin and swamp white oak are recorded as rare to abundant. From the data at hand it appears that these oaks were usually only rare to frequent secondary species in the elm-ash-soft maple community of northern Ohio, and that the yellow birch was entirely absent in the swamp forests of northwestern Ohio.

In the column representing the bur oak-big shellbark hickory transition, or the wetter phase of the elm-white ash-red maple association, bur oak and big shellbark hickory are recorded as rare to abundant. They reached their greatest abundance in the swamp forests of northwestern Ohio.

In the column representing the red oak-linden transition, or the better drained phase of the elm-white ash-soft maple community, many secondary species are recorded. Several of these species frequently become abundant in this phase of development of the swamp forest formation in northern Ohio; principally red oak, shagbark hickory, linden, bur oak, and big shellbark hickory; while yellow oak, red elm, and bitternut hickory became conspicuous secondary species. In the best drained phases of the swamp forest formation tulip and walnut become abundant enough in certain habitats to be classed with the dominants.

This variation in relative abundance of species results in the development of several forest communities in the swamp forest formation. Which of these communities are extensive enough to be recognized and named? What are the most appropriate names for them? Satisfactory answers to these questions may be obtained only by a combined study of the

records of early surveys and present field studies, including inquiry among men who removed the virgin forests.

Sears* has studied the early surveyor's records of this region but his published data while helpful are too generalized to aid in the solution of some of the problems. Data from all of these sources were brought together in the present survey, but so much more remains to be done that only tentative answers may be proposed for the above questions at the present time.

The local abundance of yellow birch in the elm-black ash-red maple association in northeastern Ohio occurs in those habitats, principally bogs, that were dominated by communities of the Northern Evergreen Forest Formation until very recent times. The elm-black ash-red maple-yellow birch community, therefore represents a particular transition in the succession from the Northern Evergreen to the Deciduous Forest Formation.

Excessive abundance of pin oak and swamp white oak in the virgin forests of northern Ohio seems to have been quite local and probably associated with the occurrence of heavy clay soils. A pin oak type is already recognized by foresters, and it is perhaps sufficient merely to recognize that transitions may exist between the pin oak community and the elm-ash-soft maple community.

Bur oak was an important secondary species in the virgin elm-ash-maple community in northwestern Ohio. Much of it was cut for the building of ships in the early days of settlement. The area over which bur oak should be classed as a dominant along with elm, ash, or big shellbark hickory is undetermined. Perhaps this community is not extensive enough to deserve a special name except as a local variant, since a bur oak-elm association that succeeds wet prairie is already recognized.

Owing to the great number of species involved a much more complex situation is met when the forest communities corresponding to the red oak-linden transition in the successional series are considered. Since several of these secondary species of the elm-ash-soft maple community may occur as dominants in certain areas, several combinations of dominants are possible and several resultant forest communities may occur. Perhaps the most helpful classification of these communities will result from a general agreement among foresters and ecologists to

*Sears, P. B. The natural vegetation of Ohio. Ohio Jour. Sci. 25: 139–149, 1926. Ibid 26: 213–231, 1927.

choose one or two names such as red oak-linden-ash, red oak-linden-elm, or the mixed red oak-linden-ash community, that have a wide geographical significance and to consider the remaining combinations wherever found as variants. For example, in certain habitats in Portage County, Ohio, one might recognize an elm-shagbark hickory-red maple variant of this community. The remaining species of the red oak-linden transition occur in this variant but are rather infrequent. As a result of this variant in the successional series before invasion and dominance by beech, wet beech forests with elm, hickory, and red maple as the principal secondary trees are sometimes found in Portage County. In some variants the oaks and hickories characteristic of the elm-ash-soft maple community are so abundant in the least disturbed swamp forest relicts in northwestern Ohio that the forests have the characteristic physiognomy of an oak-hickory association. They can be distinguished from the upland white oak-black oak-hickory association only by their species composition.

The climax of luxuriance is reached in the swamp forest formation when drainage becomes sufficient for tulip, walnut, and magnolia to intermingle with the other species of the elm-ash-soft maple community. In certain habitats where the soil is composed of sandy or gravelly loam, tulip and walnut may be as abundant as the other dominants of the forest community. In special habitats where several species of this tulip walnut transition become about equally abundant, and in which beech and maple have become fairly common as a result of further drainage, the resultant mixed forest community resembles the mixed mesophytic community that sometimes develops as a special transition between beech maple and oak-chestnut. But this point will receive further consideration in a later paper.

Local societies of single species also occurred in the virgin swamp forests of northern Ohio. The early settlers report small areas of almost pure stands of cottonwood, black walnut, sycamore, elm, tulip, hickory, and pin oak. Pure stands of cottonwood are reported occupying as much as forty acres. John Coutches reports a pure stand of walnut covering almost a section of land on the site now occupied by the Standard Oil Company in the eastern part of Toledo. "The soil contains much sand, and mushrooms (morels) grew abundantly. Walnut

was also exceedingly abundant on some of the floodplains rich in sandy or gravelly loams."

The types of variations in the swamp forest communities discussed above may be found within the limits of a single county. When observations are extended over a wider geographical range, variations resulting from the elimination of certain species are found. Such variations are illustrated in Ohio by the absence of hemlock, yellow birch, pine, and magnolia in the Black Swamp of northwestern Ohio, and by the absence of sweet gum and river birch in northern Ohio. When the area is extended to include the swamp forests of Kentucky and Arkansas, several other variations in floristic composition and in relative dominance are encountered.

FACTORS UNDERLYING THE RELATIVE ABUNDANCE OF SPECIES IN THE DIFFERENT SWAMP FOREST COMMUNITIES.

In the above topic attention was called to the increase in relative abundance of tulip and walnut upon sandy and gravelly loams and of pin and swamp white oak upon certain heavy clay soils. Earlier in the paper attention was called to the outstanding effects of moisture and soil aeration upon the habitat range of the various tree species in northern Ohio, and upon the order in which these trees invaded the swamp habitat. The effect of shade in habitats occupied by beech-maple is shown in the chart by the greater abundance of these species in habitats both too dry and too poorly drained for beech-maple. Similarly certain species of the swamp forest formation may overshade other swamp forest species and decrease their abundance in certain habitats.

While drainage conditions, soil aeration, and the complex of factors underlying geographical distribution may account for the presence or absence of a species in one or more of the communities that make up the successional series of the swamp forest formation in northern Ohio, the explanation of local variations in relative abundance of a species within a particular community, such as the red oak-linden transition, in which the given species normally grows must also take into account the influence of several other factors, such as biotic competition, pre occupation by approximately ecological equivalents, biotic history of the habitats, and time and rate of succession.

Soil types have been proposed as an explanation of the distribution and composition of plant communities. The study of the relations of vegetation types and soil types is a fruitful field of research, and soil maps are of great aid to the biologist in indicating where changes in vegetation types may be expected. The soil type as it is mapped, however, represents a complex of factors, and therefore may not be relied upon to delimit the particular factor or factors of most importance biologically. In previous reports* the writer called attention to the fact that the soil type alone may decidedly fail to account for either the composition or the distribution of plant communities. For example under natural conditions the plant communities of marsh and wet prairie, and the transitional phases and communities of the swamp forest formation occurred upon the same soil type—Clyde silty clay loam—within the limits of one county. Furthermore these different plant communities also occurred upon Newton clay loam, Newton silty clay loam, and most of them upon Brookston silty clay loam within the same county. It is obvious therefore that different vegetation types may occur upon the same soil type, and that the same vegetation type may occur upon several soil types. But if we study all of these relations between a certain vegetation type and several soil types, the particular factors in the soil that influence the vegetation type may become evident.

SECONDARY SWAMP FOREST COMMUNITIES.

Several factors determine the nature of secondary swamp forests. Secondary forests may be little different from the virgin forests. Many of the secondary swamp forests of northern Ohio are claimed by the early settlers to be good examples of what grew there originally. Again secondary forests may consist mainly of secondary species of the virgin forest either in pure or mixed stands. This last condition may occur following a single clearing, but it is more likely to occur following repeated clearings or when grazing or cultivation intervenes between clearing and reforestation. Attention should also be called to the fact that numerous areas in the state now

*Sampson, H. C. Vegetation types and soil types of Marion County, Ohio. Ann. Assoc. Amer. Geog. 20: 40–41, 1930. Advantages and limitations of the use of the distribution of soil types as a basis of mapping the distribution of vegetation types. Proc. Ohio Acad. Sci. 40: 390–391, 1930.

occupied by secondary communities of swamp forest species were originally covered by beech-maple forests.

A comprehensive survey of secondary forests remains to be made. Attention, however, may be called to the relation of secondary swamp oak-hickory forests to the transitional phases of the swamp forest in northern Ohio. Beginning with the wettest phases of the elm-black-ash-soft maple community, the corresponding secondary swamp oak-hickory forest that may occur is given to the right in the following summary. The number of species of oak and hickory increases with each successive phase since species of the wetter phases still persist in the better drained phases.

Successional Phases of the Virgin Elm-Ash-Soft Maple Community:	Corresponding Secondary Swamp Oak-Hickory Forests:
1. Elm-Black Ash-Soft Maple Association.	Pin Oak-Swamp White Oak.
2. Bur Oak-Big Shellbark Hickory transition.	Bur Oak-Shellbark Hickory with Pin Oak, and Swamp White Oak.
3. Red Oak-Linden transition.	Red Oak-Hickory. Pin, Swamp White, Bur, and Yellow Oaks. Shellbark, Shagbark, and Bitternut Hickories.
4. Tulip-Walnut transition.	Similar to the one above.

The order of invasion of the swamp forest by beech and white oak is variable. Beech is usually first but not always. Beech is decidedly an earlier invader than hard maple. When a wet beech-maple forest is cleared the corresponding secondary oak-hickory forest which sometimes follows includes white oak in addition to the oaks listed above. The white oak-black oak hickory and the oak-chestnut-hickory association are characteristic of upland not of swamp habitats.

THE MIXED MESOPHYTIC FOREST COMMUNITY OF NORTHEASTERN OHIO.*

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Botanists and foresters working in the deciduous forest area of the Eastern United States frequently encounter mixed communities of mesophytic trees that cannot be readily classified by means of the binomial or trinomial terms in general use. Neither are these mixed communities the usual transitional zones dominated by the dominant species of the two "competing" associations. They are generally characterized by an unusual increase in abundance of several of the commonly occurring secondary species intermingled with the dominants of from two to three or more associations.

Griggs[1] called attention to the diversified forests of some of the coves of the Sugar Grove region of Ohio. Miss Braun[2] recognized a mixed mesophytic forest in the Cincinnati region. Frothingham, *et al*[3] described under the heading of "cove hardwood type," a mixed forest community in the Southern Appalachian Mountains. They report that this forest type in the Southern Appalachians occupies moist coves or ravines with their adjacent lower slopes, sometimes extending for some distance up protected slopes of north exposure. When Transeau first attempted to classify the forest communities in central and eastern Ohio he became convinced that it was necessary to recognize a mixed mesophytic forest community. He first called my attention to it in 1917. Since then we have seen numerous areas of it in Ohio and adjacent states. In a recent reconnaissance survey of the southern states Transeau[4] concluded

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*Papers from the Department of Botany, the Ohio State University, No. 263.

[1]Griggs, R. F. A botanical survey of the Sugar Grove region. Bull. No. 3, Ohio Biol. Survey, Page 273, 1914.

[2]Braun, E. Lucy. The physiographic ecology of the Cincinnati region. Bull. No. 7, Ohio Biol. Survey, 1916.

[3]Frothingham, *et al*. A forest type classification for the Southern Appalachian Mountains and the adjacent Plateau and Coastal Plain regions. Jour. Forestry 24: 673–684, 1926.

[4]Transeau, E. N. Vegetation types and insect devastation. Ecology 8: page 286, 1927.

that the mixed mesophytic forest of Ohio is a northward extension of the magnificent forests of the lower slopes of the Great Smokies and the dissected Allegheny plateau of eastern Tennessee.

The mixed mesophytic forest community has not been generally recognized as such, neither has it received a critical ecological analysis. Very little is known of the variants that will need to be recognized when it is studied throughout its entire geographical and altitudinal ranges. The conditions under which the mixed mesophytic forest develops in northeastern Ohio appear to be relatively simple. The data in this report are presented for what value they may have in the way of suggestions.

The accompanying chart (Chart I) showing the approximate habitat range of species occurring in the mixed mesophytic forest community of northeastern Ohio is sufficiently accurate in detail to show (1) the composition of the mixed mesophytic community, (2) that it is characterized by an increase in abundance of secondary species intermingled with the dominants of two or more associations, (3) that it appears to be a special type of transitional community occupying a position between dry sites covered by oak-chestnut and moist sites in which the complex of factors is favorable to the dominance of beech-maple, and (4) that there are sufficient differences in drought resistance of the species involved and the consequent order of their invasion of the oak-chestnut association with increasing moisture that considerable variation in the composition of the mixed mesophytic community may occur locally.

The chart is constructed on the same plan as the chart described in the previous paper on the swamp forest formation of northern Ohio, with the exception that the present chart shows the order of invasion of the oak-chestnut community by the trees found in the mixed mesophytic community. Owing to lack of space the names of the four forest communities of the swamp forest formation indicated in the chart were omitted. Reading from left to right they are the tulip-walnut, red oak-linden, bur oak-big shellbark hickory transitions of the elm-white ash-red maple community, and the elm-black ash-soft maple association described in the prvious paper. The two vertical broken lines in the chart enclosing a part of the oak-chestnut community and a part of the mixed mesophytic community were added to indicate an intermediate community

CHART I

Chart showing the approximate habitat range - horizontal lines - of trees occurring in the Mixed Mesophytic Community in northeastern Ohio. The relative abundance of each species when present is indicated by the following symbols: a = abundant, c = common, f = frequent, o = occasional, r = rare. The Mixed Mesophytic Community is limited to particular sites in which several secondary species become relatively abundant together with the dominant species of two or more associations.

Species	Oak-Chestnut Community	Mixed Mesophytic Community	Beech-Maple Association	Transitional phases of the Swamp Forest Formation
Quercus coccinea Scarlet Oak		r-o		
Quercus velutina Black Oak		r-f		
Quercus primus Chestnut Oak		r-f		
Castanea dentata Chestnut		r-a	r-c	
Nyssa sylvatica Sour Gum		r-f	r	r-c
Acer rubrum Red Maple		f-a	r-c	f-a
Sassafras variifolia Sassafras		r-f		
Cornus florida Flowering Dogwood		o-f	r-f	o-f
Amelanchier canadensis Shad Bush		r-o		
Prunus virginiana Choke Cherry		r-o		
Carya microcarpa Little Bitternut Hickory				
Carya glabra Pignut Hickory		r-c	r-f	
Quercus alba White Oak		r-a	r-c	r-f
Quercus Muhlenbergii Yellow Oak		r-c	r-f	r-c
Carya alba Mockernut Hickory		r-f	r-f	
Prunus serotina Black Cherry		r-f	r-f	r-f
Fraxinus americana White Ash		r-a	r-c	r-a
Fraxinus lanceolata Green Ash		r-f	r-f	r-f
Ulmus fulva Red Elm		r-c	r-f	r-c
Carya ovata Shag-bark Hickory		o-f	o-c	f-a
Quercus rubra Red Oak		r-a	r-c	f-a
Carya cordiformis Bitternut Hickory		r-f	r-f	r-c
Juglans cinerea White Walnut		f-c	r-o	r-c
Juglans nigra Black Walnut		r-c	r-o	r-a
Magnolia acuminata Cucumber Tree		r-a	r-f	r-f
Liriodendron tulipifera Tulip Tree		f-a	r-c	r-a
Ostrya virginiana Hop Hornbeam		r-f	r-f	r-o
Morus rubra Red Mulberry		r-f	r-o	r-f
Carpinus caroliniana Blue Beech		r-f	r-f	f-c
Tilia americana Linden		r-c	r-c	r-a
Fagus grandifolia Beech		r-a	c-a	r-f
Acer saccharum Sugar Maple		r-a	f-a	
Acer nigrum Black Maple		r-a	f-a	
Ulmus americana American Elm		r-c	r-c	c-a
Tsuga canadensis Hemlock			r-c	r-a

which is variously referred to as oak-tulip, oak-chestnut-tulip, or dryer phase of the mixed mesophytic community depending upon variations in its composition, and also upon the different objectives an observer may have in making classifications of forest communities.

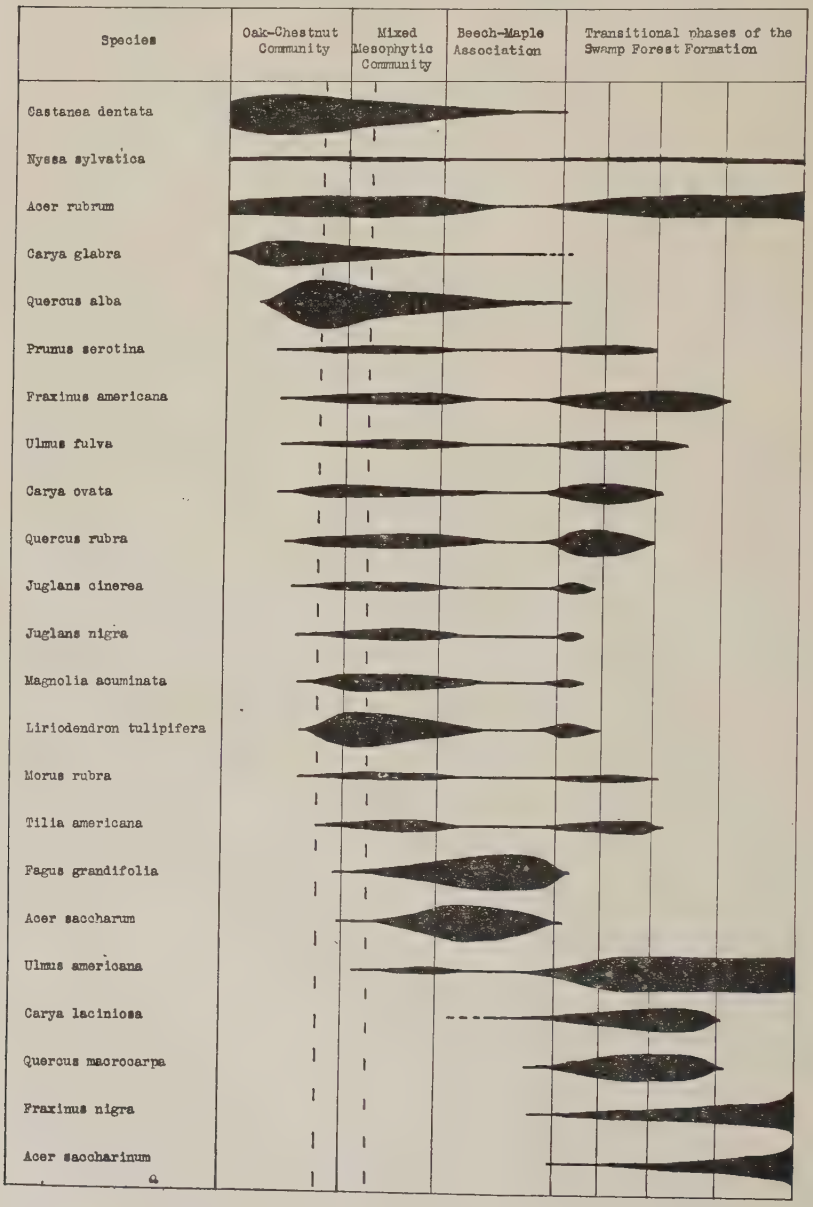
The first ten species listed at the top of the chart occur in the dryest oak-chestnut forests found in northeastern Ohio. An attempt was made to list the remaining species in the chart in the approximate order of their invasion of the oak-chestnut forest with increasing moisture. Major attention was given to the order of invasion of the oaks, hickories, tulip, magnolia, beech and hard maple. The number of observations made was not as large as desired, and perhaps the order of some of the species is incorrectly listed. Furthermore the order of invasion of some of the species is modified somewhat by the nature of the substratum, being different for sand, rock outcrops, and clay. The possibility of a few minor errors, however regretable, does not annul the major facts illustrated by the chart.

The chart shows the relative distribution of the species under the combined effects of all the factors of the natural habitat, primarily the combined effects of the moisture gradient, soil aeration, and shade. Wherever man interfers with the factors of "natural competition" the habitat range of a species often becomes extended.

The species frequently found occupying first place in the mixed mesophytic community of northeastern Ohio on the basis of number of individuals present are beech, sugar, black, and red maple, tulip, magnolia, chestnut, white and red oak, and white ash. Somewhat less abundant, but decidedly more abundant than they occur as secondary species in the beech-maple association are red elm, black and white walnut, linden, black cherry, sour gum, flowering dogwood, pignut, bitternut, shag-bark, and mocker nut hickories, red mulberry, and american elm. Chestnut oak and hemlock are of very local occurrence in northern Ohio. The mixed mesophytic community is referred to above as a special transitional phase with the distinction in mind that any transitional forest in which the dominants of the two "competing" associations remain dominants of the transition and the secondary species continue to remain subordinate should be referred to merely as a transition. For instance, an oak-chestnut beech-maple transition in which only oaks, chestnut, beech, and maple are the dominant trees.

CHART II

Chart showing where the maximum abundance of individuals of a species may occur in virgin plant communities of which the species is a member. The relative endurance of poor soil aeration, shade, and drought by the different species in the chart is exemplified. The data also illustrate transitional phases, and the dominance of beech and hard maple in certain habitats.



Attention is particularly called to the invasion of the oak-chestnut association with increasing moisture by such species as white and red oaks, magnolia, tulip, white and black walnut, mockernut, shagbark, and bitternut hickories, white and green ash, and cherry before the entrance of beech and hard maple. When several of these species become abundant it is necessary to recognize either an early dryer phase of the mixed mesophytic community or a luxuriant phase of the oak-tulip or the oak-chestnut-tulip community* in which beech and hard maple are either absent or appear only as scattered small undergrowth trees. With increasing moisture beech and hard maple through increase in size and abundance also assume the rank of dominants, though in the mixed mesophytic community they were apparently often overtopped by oaks, chestnut, tulip and magnolia.

In northeastern Ohio beech invades the oak-chestnut association earlier than hard maple. This fact appears to account for the absence in northeastern Ohio of the oak-maple community that is frequently found as one approaches an oak-hickory and prairie climate.

Other variants of the mixed mesophytic community include (1) local variation in the relative abundance of individual species such as tulip, magnolia, oaks, chestnut and walnut, and (2) elimination of species beyond their geographical range. As one crosses northern Ohio from east to west, hemlock, chestnut, and magnolia drop out. The mixed mesophytic community on limestone outcrops in northen Ohio differs from the one described in having a greater abundance of yellow oak and blue ash and no chestnut. Altitudinal and geographical variants throughout the entire range of the mixed mesophytic community have been but partially analysed at present.

A second chart (Chart II) showing where the maximum abundance of individuals of several tree species may be found in northern Ohio further emphasizes (1) the possibilities of transitional variants, (2) the dominance of beech and hard maple in certain habitats and (3) the similarity of the mixed mesophytic community and the mixed swamp forest transition that sometimes develops on areas slightly too poorly drained for the dominance of beech and maple as previously described for northern Ohio.†

*This community is indicated in the charts by the two vertical broken lines.

†Sampson, H. C. Succession in the Swamp Forest Formation in Northern Ohio. Ohio Jour. Science, 30: 340–357, 1930.

The secondary species of the beech-maple association in northern Ohio include all of the species listed for the mixed mesophytic community. But where the habitat conditions are most favorable for beech and maple their dominance is very effective, and the secondary species occur only as scattered and occasional trees. Attention is also called to the fact that certain species especially tulip, magnolia, the walnuts and hickories, red and yellow oak, cherry, linden, red elm, and white ash, endure slightly less drainage than beech and hard maple. Consequently they sometimes become abundant in the best drained phases of the swamp forest before conditions are favorable for the dominance of beech and hard maple. It appears, therefore, that but for the dominance of beech and hard maple, the mixed mesophytic forest community in northeastern Ohio might occupy a much larger portion of the area exhibiting the soil-moisture gradient within the range favorable to such species as tulip and magnolia.

Two questions, therefore, arise. What are the conditions that favor the dominance of beech-maple and restrict the mixed mesophytic community to certain local habitats in northeastern Ohio? Is the mixed transitional swamp forest that sometimes develops on areas not quite sufficiently drained for the dominance of beech and hard maple a phase of the mixed mesophytic community already described as a special transitional phase between oak-chestnut and beech-maple?

For an opinion on the last question reference should be made to the charts presented in this paper and to the chart in the earlier paper on the "Succession in the Swamp Forest Formation in Northern Ohio." On the basis of the data presented in the charts it is obvious that the mixed mesophytic community described above and the mixed transitional swamp forest community sufficiently drained for the entrance of tulip, magnolia, the walnuts, and frequent individuals of beech and hard maple have much in common. They differ primarily in three respects. First in their vegetational history. The one succeeds the elm-ash-soft maple community as the result of the filling and drainage of swamp habitats, while the successional relations of the other are associated with the beech-maple and oak-chestnut communities. Secondly they differ in the presence and absence of certain secondary species; the one having certain secondary species holding over from the oak-chestnut association, the other having certain secondary species holding over from the

elm-ash-soft maple association. In the third place there is a difference in the proportion of the principal species. For instance american elm, red oak, ash and linden are relatively more abundant in the mixed swamp forest transition, while such species as white oak, chestnut oak, and chestnut are rare or entirely absent. Perhaps one may be regarded as a wetter phase, the other as a somewhat dryer phase of the mixed mesophytic community. If they may be so regarded it follows that the mixed mesophytic community in northeastern Ohio has a somewhat wider soil-moisture gradient than beech-maple and is eliminated from the middle portion of this range wherever edaphic conditions are most favorable to the dominance of beech-maple.

The habitats in which the mixed mesophytic community occurs in northeastern Ohio appear to have certain conditions in common, but these conditions may not hold throughout its entire geographical range since the influence of Lake Erie may be a factor and still other factors may become more prominent elsewhere.

Northeastern Ohio includes a portion of the glaciated area of the Allegheny plateau. The streams are relatively young with narrow flood plains and medium sized valleys 100 to 200 feet below the level of the surrounding country. The climate is sufficiently moist for the beech-maple forest through out the entire range in altitude from about 580 feet near Lake Erie to about 1200 feet on the divide between the Lake Erie and Ohio River systems in Portage and Trumbull Counties. Owing to differences in physiography and soils numerous local areas are not covered by a beech-maple forest but are occupied by relict bogs, conifer bog forests, swamp forests, beech-maple-birch-hemlock forests of gorges and deep valleys, oak-chestnut, and mixed mesophytic communities. The most extensive development of the last two communities named above occur on the gravelly hills of the interlobate moraine and the slopes of the Cuyahoga River from near Burton in Geauga County southward beyond Massillon in Stark County.

The mixed mesophytic community occurs at all altitudes from that of the old lake bed near Lake Erie to the top of the divide. Its restriction to local habitats in northeastern Ohio appears therefore to be due entirley to edaphic conditions, local exposure, and the supreme dominance of beech-maple in

certain habitats. The local habitats in which it is found may be summarized as follows:

1. Slopes of valleys in which the soil is a mixture of decaying rock fragments, loose soil, and humus. Narrow belts occur at various places on slopes of several valleys where the succession with accompanying physiographic changes may be (1) beech-maple on upland ⟶ mixed mesophytic on slope ⟶ beech-maple on flood plain, or (2) beech-maple on upland ⟶ oak-chestnut on ledge ⟶ mixed mesophytic on slope ⟶ beech-maple on flood plain. Similar slopes physiographically but with heavy soils with poor internal drainage are covered by beech-maple.

2. Slopes of hills of the interlobate moraine where the successional relations are oak-chestnut ⟷ mixed mesophytic ⟷ beech-maple depending upon whether the change is from dry to moist conditions or the reverse.

3. Four exceptions to slope habitats were found: (1) gravel-rich swales between hills of the interlobate moraine with sufficient drainage to exclude lake and bog formation, (2) occasional high terraces between slopes covered with mixed mesophytic forest, (3) low sand ridges on swamp forest areas on the old lake beds, and (4) similar low ridges of sandy loam on top of a wet flat upland near to the top of the divide in Trumbull County.

All of the above habitats occupied by the mixed mesophytic community, therefore, appear to be alike in having soils with a good supply of water and at the same time with good internal drainage. Slopes with heavier soils and poorer internal drainages are covered by beech-maple. The dryest habitats are covered by oak-chestnut. Certain rocky slopes with numerous irregularities in depth of soil are also favorable sites for mixed forests.

The soil types that appear most favorable to the development of the mixed mesophytic community in northeastern Ohio are certain areas of Wooster loam and gravelly loam, Volusia loam, and Dunkirk sand, but other forest associations are also found on these soil types. The location of the soil types named above was obtained from published maps. Attention should also be called to the fact that the soil survey of this area was made before the methods of soil survey reached their present state of development. Apparently modern soil surveys

will be more helpful in detecting some of the important edaphic conditions that become controlling factors over local areas.

Secondary associations that follow the cutting of a mixed mesophytic forest community are dependent not only on the varied methods of cutting and the subsequent activities of man on the area but also upon the composition and phase of development of the community that is cleared. The community may reproduce itself with but slight variations from the original, but there is usually a noticeable change in composition. On the dryer sites oaks, chestnut and hickories often become the most abundant trees. On moist sites cherry, ash, elm, tulip, walnuts, red oak, and maple may become the most abundant species. On favorable sites beech and hard maple increase in abundance in secondary forests following selective cutting of oaks, chestnuts, tulip, and magnolia in mixed mesophytic forests.

ANOMALOUS POST CAVAL VEINS IN A CAT.

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ABSTRACT—"*Anomalous Post Caval Veins in a Cat.*" A description is presented of an adult Cat with paired Post Caval Veins, Vena Cava Posterior or Inferior. These extend, without any other anastomosis, anteriorly, to a point between the two kidneys, and from there continue as one vessel. This point of fusion is three and one-half inches anterior to the usual junction of the leg vein, Iliacs. The left ovarian vein joins the left one of the Post Cavæ at a level posterior to the kidney of that side, instead of being a continuation of the left renal vein. The Ureters extend from a dorso-lateral to a ventro-lateral position between the paired Post Caval veins. This blood vessel pattern is interpreted as the "AD" type of Huntington and McClure, the main feature of which is the persistence of embryonic Post Cardinal veins. A labeled photograph accompanies this described variation.

Unusual blood vessels, representing persistent embryonic channels, have received special study in recent years. However, Reagan, in a recent review, ('29), has shown that not merely in our time, but at intervals during the last century, important discoveries and interpretations have been made on the eutherian vena cava. Paired post caval veins, (vena cava posterior or inferior) have been observed in several patterns as related to the aorta and ureters. From their own researches, and observations of other anatomists, Huntington and McClure ('07, '20, and '29) list seventeen possible vascular anomalies of this part of the body in mammals. Darrah ('07) found one particular anomaly in twenty out of 605 cats. All of these had paired caval veins, but six of them did not continue the common Iliac trunks on anteriorly to the kidney region without anastomoses. According to Huntington and McClure ('29), their figure 25 shows the only case of this pattern of blood vessels that has been reported for man. That case was in a fetus (from Gladstone, '12, Figure 8).

An atypical arrangement of the veins, arteries and ureters has recently been found in the Comparative Anatomy Laboratory at the University of Illinois, Urbana. From a group of five doubly injected and embalmed cats, one adult female was found with long paired post caval veins. The blood channels from the posterior limbs, the iliac veins, do not fuse until they reach a point between the two kidneys. This place of union

is three and one-half inches anterior to the usual junction. The ureters arise dorso-lateral to, and pass between the caval veins to a ventro-lateral position. Also, the left sex vein, (ovarian vein), joins the left one of the paired post cava somewhat posterior to the level of the kidney. The veins extend laterally, along with the corresponding arteries, but their origin is posterior to that of the arteries. Otherwise, the cat appeared normal.

The research of Huntington and McClure, especially, provides a rather clear-cut explanation, as far as it goes. The capillary plexus on the venous side has been found by these authors, and others, particularly for the cat and human to early develop into paired longitudinal veins of a variable extent and duration. Figure one of their memoir, '29, is a "composite diagram of embryonic veins of the domestic cat (Felis domestica) based on a detailed study of the development of the veins." A similar figure appears in their paper of '20. One pair of these longitudinal embryonic channels is known as the post cardinal pair. Ventromedially to these are the subcardinal vessels. Dorsomedially to the post cardinals are the paired supracardinals. By the dropping out of certain ones of these, or parts of a given one, the persistence of others, and connections with a venous ring in the region of the kidneys the different atypical conditions are accounted for.

This unusual, but apparently functionally normal condition is placed under the "AD" type of Huntington and McClure, '29. It represents the persistence of both posterior cardinal veins of the embryo, instead of the right supracardinal vein, which forms the normal vena cava posterior (inferior) of the cat and man. Apparently this specimen closely resembles one of the Darrah series of cats, that one illustrated by Huntington and McClure, '29, figure 20, in diagnostic characteristics. That this is the "AD" type is evident from the position of the Ureters with reference to the caval blood vessels, and further by the sex vein connection. This latter is interpreted to represent a part of the right and left subcardinal channel. The developmental history of these veins may not be so simple as here postulated. Reagan, '29, page 208, closes his reveiw of the literature on this subject by stating that, "The formation of the vena cava is a much more complicated process than any existing account would indicate."

However, these observations record another atypically paired vena cava posterior (post cava), and refer to the pair, tentatively, as persistent embryonic post cardinal veins. The cat is preserved at the University of Illinois. Figure one is a labeled photograph of this variation.

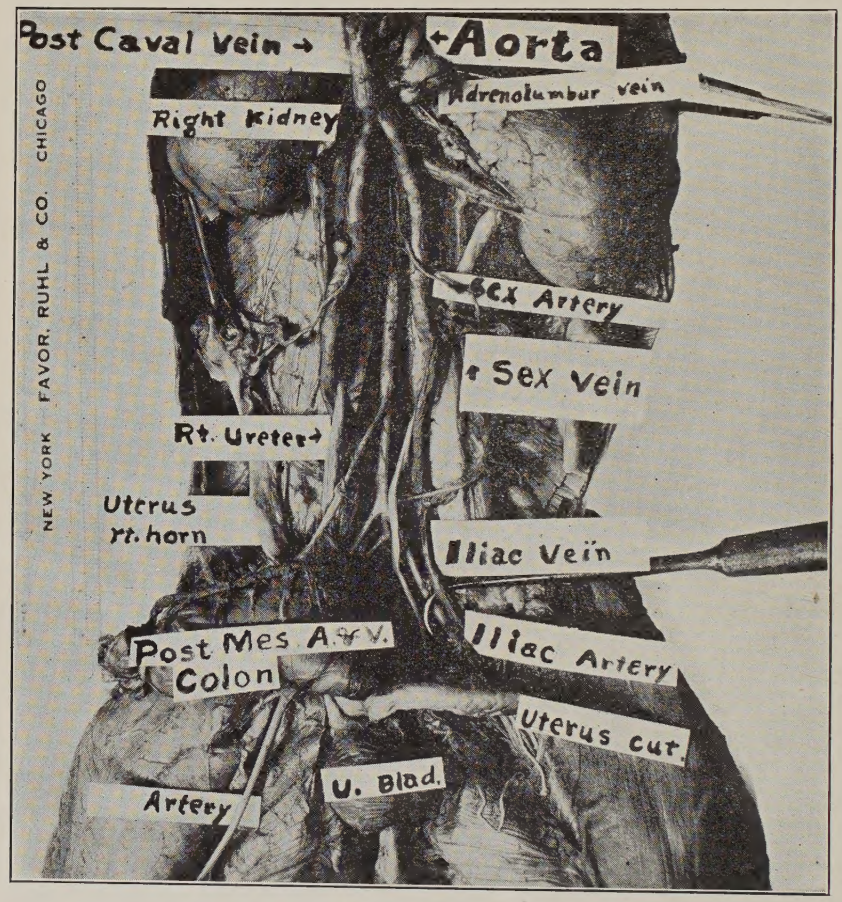

FIG. 1. CAT—Type "AD" Post Cava (Vena Cava Posterior), showing persistent embryonic post cardinal veins.

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COAL RESEARCH LABORATORY

A recent announcement through the *News Service* of the Carnegie Institute of Technology that will interest many of our readers, states that:

"Gifts totalling $425,000 to extend over a five-year period for the establishment and maintenance of a coal research laboratory at the Carnegie Institute of Technology were announced yesterday by Dr. Thomas S. Baker, president of the institution.

"The Buhl Foundation, of Pittsburgh, is the largest single donor to the project, contributing $50,000 at the outset for the equipment of the laboratory, and $25,000 a year for five years for a program of pure research. The gift of the Buhl Foundation is made with the stipulation that certain additional amounts shall be secured from other sources. This condition has now been met through the co-operation of six great American concerns who are the other contributors to the project that has been outlined by Dr. Baker. The firms co-operating are the United States Steel Corporation, the General Electric Company, the Koppers Company, the New York Edison Company, the Standard Oil Company of New Jersey, and the Westinghouse Electric and Manufacturing Company. These six corporations will contribute a total of $50,000 a year for five years for the maintenance of the laboratory.

"The laboratory, according to Dr. Baker, will be a part of the Carnegie Institute of Technology, and will undertake fundamental research in coal and the products which may be obtained from it. The Carnegie Institute of Technology will organize graduate courses for the training of students in fuel technology in connection with the research laboratory, with the research staff giving instruction.

"Mr. Myron C. Taylor, chairman of the Finance Committee of the U. S. Steel Corporation, has co-operated with Dr. Baker in outlining the plans for the research laboratory that will be unique in America. It was largely through the endeavors of Mr. Taylor that the financial aid of the industrial concerns was secured.

"Mr. Charles F. Lewis, director of the Buhl Foundation, in commenting on the laboratory that the organization which he heads has made possible, said:

" 'It is gratifying to the Buhl Foundation that to its grant have been joined sufficient additional funds to assure establishment at the Carnegie Institute of Technology of a modern laboratory for prosecution of a vigorous program of pure research in coal. Two international conferences under President Baker's direction have prepared the way for this program and give assurance that it will

have the cordial and sympathetic interest of outstanding men of science throughout the world. The probability that the laboratory may make important contributions to basic scientific knowledge is strengthened by this relationship.

" 'The Institute's research program is, moreover, of distinct economic importance to the Pittsburgh district. The development in Pittsburgh of knowledge of coal, linked with additional provisions for training here expert technicians, may confidently be expected to have important consequences not only for this basic industry and for those employed in it, but for the people generally.'

"Dr. Baker has long been interested in the study of coal and the use of its products. He was the organizer of the First and Second International Conferences on Bituminous Coal that attracted famous scientists from abroad, and drew the attention of the world to Pittsburgh. A third conference will be held in Pittsburgh at the Carnegie Institute of Technology in November, 1931.

"Dr. Baker in speaking of the research laboratory for which he has worked for several years, said:

" 'Pittsburgh is the appropriate place in which to study coal. Its industria greatness is based largely on the rich supply of fuel in this district. Its future is somewhat endangered by the unsatisfactory condition of the coal industry. It would be too much to say that science can cure all the ills of this phase of our business life, but research offers the best opportunity for solving many of its baffling problems. We are in the center of the greatest coal field and the greatest coal market in the world. It is important that the people of this district should have near at hand the best scientific resources that can be secured in the world to aid them in dealing with what is most vital to the welfare and progress of our community.

" 'Coal touches almost every phase of modern life. As far as we can see it will always be the chief source of power, and cheap power is an essential to human welfare in our present civilization. It is the source of many of the necessities of life.

" 'There is no laboratory at present in the United States that is doing the work that we have outlined. There are many uses and by-products of coal still to be developed. Finally, there is the question of the smokeless city which can never be answered until a serviceable smokeless fuel has been discovered.' "